This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

**Usage guidelines**

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

**About Google Book Search**

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

eneral Library System
University of Wisconsin-Madison
728 State Street
Madison, WI 53706-1494
U.S.A.

# Drill Work
# Methods and Costs

a

# Practical Treatise

### Covering the Methods Used in Drilling Wells With Cable and Hollow Rod Tools

by

## R. R. Sanderson

Sales Manager of The Cyclone Drill Co.

With Dimensional Tables and Illustrations Covering the Various Tools and Appliances Used

1911
Published by
The Cyclone Drill Company
Orrville, Ohio

Copyright 1911 by
THE CYCLONE DRILL CO.
ORRVILLE, OHIO

THE COURIER-CRESCENT PRINTERY
ORRVILLE, OHIO

167850

SWO

6535462

To the driller of wells, wherever he may be, this book is respectfully dedicated.

R. R. SANDERSON.

# PREFACE

In the treatise presented herewith it is not the intention of the author to attempt to make written instructions take the place of experience. To gain skill in any line of work it is necessary that a certain period of apprenticeship be passed through. Especially is this so in well drilling, as in this work the most important operations are conducted out of sight of the drill man, and thus information regarding the action of the tools must be gained through a sort of sixth sense which can be acquired only by practice.

However, the author fully believes that the apprenticeship, spoken of above, can be served without a personal instructor if the beginner is provided with instructions of the proper kind, and it is with the intention of supplying such instructions that this book has been written.

In compiling the instructions, the object kept in view was to tell not only how a thing should be done, but also why it should be done as advised, thus explaining the principles lying back of the work. It is to be expected that some of the methods advocated will not meet with the approval of all drill men, but inasmuch as the reader will find reasons accompanying each method advocated, he is in a position to vary the methods as soon as he finds that his drilling conditions are such that other reasons outweigh the ones given. It must be borne in mind, however, that in drill work a mere opinion is not a reason unless it has been formed after careful consideration and ample experience.

It is very likely that after a first reading of the instructions a beginner will get the impression that there is considerable risk connected with drill work, due to frequent references made regarding troubles which might arise unless certain precautions are taken. While it is not the aim of the author to menace the beginner with disaster and while it is very likely that fishing jobs will be few and far between, if ordinary precautions are taken, still it will be found that in the large majority of cases the most prosperous drill men are those who pay the closest attention to the seemingly little things, and thus the reader's attention has been directed not only to the manner in which drilling tools should be handled, but also, in many cases, to the troubles which can arise unless the tools are operated as instructed.

It will also be noted that considerable space has been devoted to the handling of fishing jobs and other unusual conditions and while it is very probable that a drill man engaged in shallow, water-well work will have need for but a few of these instructions, still the author would urge a careful reading of this section as the driller who has a full understanding of the troubles which can arise is very apt to use the necessary precautions to prevent their occurrence.

The author desires to extend his thanks to the great number of drill men who have offered him advice and information in the years that he was engaged in drill work and also later while he has been connected with The Cyclone Drill Company, and to acknowledge his indebtedness to them for many of the methods given herewith. Thanks are also due the manufacturers of pumping machinery for cuts loaned and for assistance extended. To Mr. B. G. Cope, President of The Cyclone Drill Company, the thanks of the author are particularly due for the advice and help which were so often sought and always so freely given.

R. R. SANDERSON.

# EXPLANATORY

In the following pages we do not attempt to present an exhaustive treatise on well drilling, neither do we attempt to go out of the beaten paths and recommend new and untried methods.

Our aim is not to advance new theories but to present plain, solid facts which have been proven by years of experience in the field in "making hole."

Our reason for preparing this book is to try and present to those purchasers of our drills who are not experienced in the drilling business, brief, but trustworthy instructions for the operation of our cable outfits.

As the drilling of deep wells, involving the use of heavy strings of tools and the handling of long lines of casing, are engineering feats requiring, for their successful handling, much experience, they should never be attempted by a beginner and thus for this treatise, we do not enter into a discussion of this class of work.

It may be thought by some that many of our descriptions are made with needless minuteness, but we would rather err on the side of going too far than not far enough.

Wherever the descriptive matter has been of such a nature that it is rather difficult to figure out, we have used cuts to help make the matter perfectly clear.

It will be found that many little "kinks" and ways are advised for most easily and rapidly handling the work, and while a great many of these methods have been gathered from suggestions made by other drillers, they have all been tried out by the writer and have thus been tested out by actual working experience.

## Testing Machines.

All Cyclone Drilling Machines are completely assembled and tried out under their own power before leaving the factory. By this method of testing we are absolutely sure that every machine is perfect in all its working parts.

After testing, the machines are more or less dismantled, according to the distance and manner to be shipped, and all parts as soon as taken from the machine are placed in the boxes to be used for them in shipping. This dismantling work is done under the supervision of one man, whose business it is to look after this one thing, and thus we eliminate, as far as human power can do so, all chance for error in sending out a proper and full equipment.

We suggest, therefore, that if on putting the machine together all the parts do not seem to be there, that, before writing us reporting a shortage, you check over the outfit very carefully.

## Unloading Machines.

If the machine is for use in this country it will probably arrive by rail and will be loaded on a gondola car with drop ends.

At the factory we have our own loading platform and the machines are pulled directly onto the car, but in unloading unless you can unload directly onto a platform, the easiest way is to back the machine off on good heavy timbers. Secure some planks 12, 14 to 16 feet long, about 3 inches thick, and at least 8 inches wide, the wider the better, and place them firmly at end of car, so spaced that the wheels strike them fairly. Fasten the ends of plank which go to ground so that they will not slip endwise or sidewise, and if the machine to be unloaded is one of our traction outfits or heavy machines, it is best to put some cribbing under the planks. Fasten set of blocks to front end of machine with other end fastened to end of car, and by snubbing the fall line from blocks around a pole fastened firmly in coupling blocks of car, the machine can be safely and quickly unloaded.

## Putting on Fittings—Engine Fittings.

It is best to put fittings on machine as soon as it is unloaded, and on the traction outfits this is absolutely necessary if the machine is to be moved under its own power.

The fittings for engine will all be found in the tool box and are as follows:

1 Engine Grease Cup for top of steam chest.

3 Globe Valve Stems with union rings to fit the relief valves in cylinder and steam chest.

3 or 4 (depending on style of machine) Grease Cups for main bearings.

1 Compression Grease Cup to be screwed into the small hole in the side of connecting rod, through which the crank bearing is lubricated.

2 Oil Cups with Caps to be screwed into the small elbows on side of engine and used for oiling the engine slides.

1 1-in. Globe Valve Stem with union ring for drilling throttle.

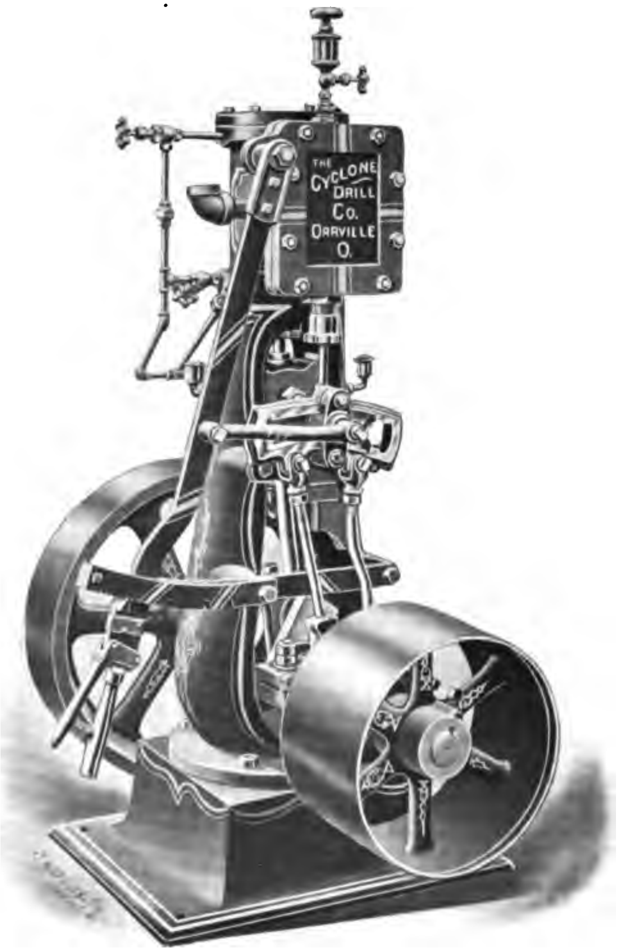
1 ¾-in. Globe Valve Stem with union ring to be screwed into steam line blow-off valve which is on pipe that extends in front of bolster below engine.

It will be noticed that all valves in place on the machine and all oil holes, and holes for oil cups, have been either wrapped with burlap or stuffed tightly with waste to prevent dust and cinders from entering while in shipment.

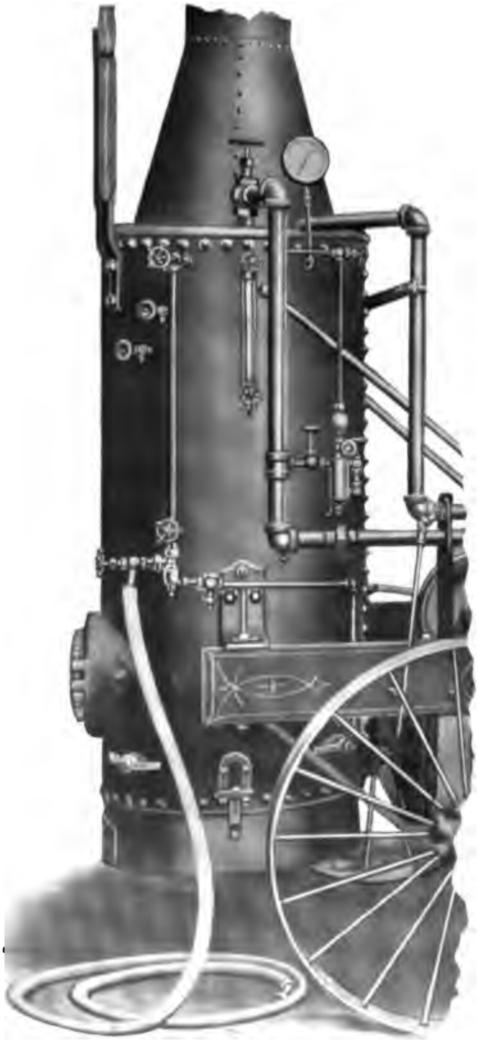
Carefully clean all valve seats and valves before screwing them together, and in setting up the union ring on valves, be sure to see that the valve stem is screwed outward as far as possible. If these precautions are taken the valve seats will not be scratched or strained.

Before placing the oil cups on engine and machinery, be sure to remove all waste in oil holes and to clean out holes thoroughly. Also clean out oil cups carefully. This will prevent grit from coming in contact with bearings, and if the above precautions are taken and the bearings are kept properly lubricated they will last for years.

In all places which are not lubricated by grease cups it is best to place some *wool* waste, as this will prevent grit from coming in contact with the wearing surfaces and will hold the oil and feed it regularly to the bearings.


THE CYCLONE DRILL CO. ORRVILLE O.

## Boiler Fittings.



The accompanying cut shows all boiler fittings, except pop valve, as used on portable outfits. The Traction machines are equipped with practically the same fittings except that it is necessary to add a quick opening throttle at boiler and one or two other attachments which add to the convenience of operation of the machine.

All fittings and pipes used for fitting up the boiler are fitted at the factory and are of correct dimensions so that all parts should go together without undue strain.

The stack is provided with hinge and is held in place when drilling by a set nut. When derrick is to be lowered the set nut is released and stack swung down out of the way.

The ash pan is held in place by two arms which extend up past brackets on side of boiler, two wedges being driven in to hold the pan firmly to the boiler shell.

The pop valve which does not show is placed in the top sheet of boiler on the opposite side of stack.

The steam gauge is usually placed with the face towards the drilling end of machine so that the driller can at all times see the pressure being carried.

## Setting Up the Machine.

After the location of the drill hole has been determined set the machine so that the point selected is in direct line with the center of machine and about 3 feet 3 inches from the axle. Place good heavy planks under the wheels which support the derrick end of machine, and if the ground is very soft it is best to place planks under all the wheels.

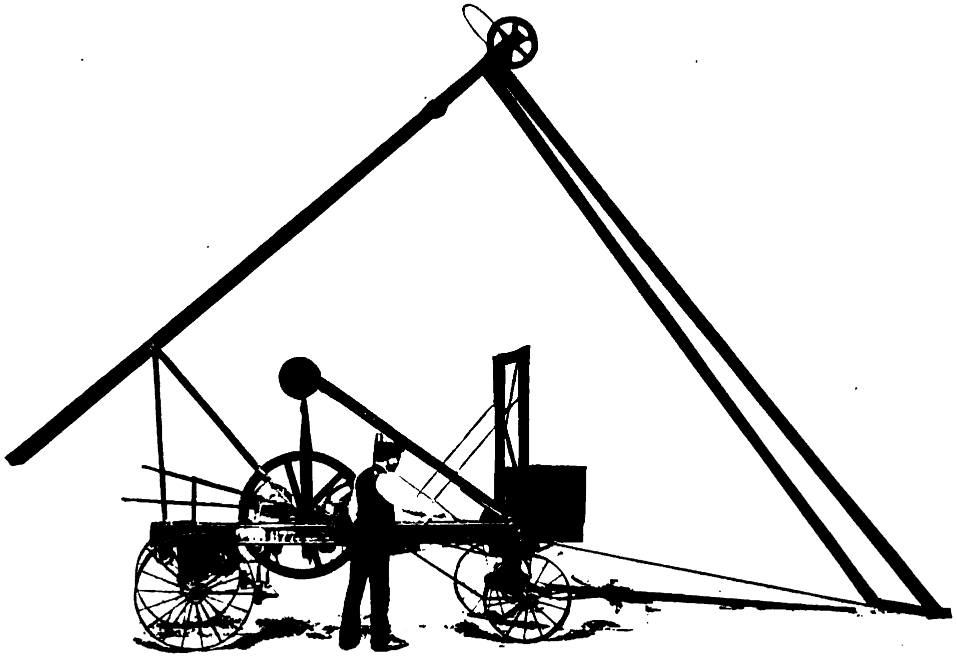
Level the machine, either by placing additional planks under the wheels which are lowest down or by digging out from under the ones which are high. If the walking beam is not to be used it is not necessary to level up the machine endwise, but in any case it is best to get it approximately so.

## Raising the Derrick.

Slip the derrick braces onto the large bolt which extends through the derrick below the crown pulley, leaving the braces extend in a line with the derrick out past the boiler, and then run up the nuts on the bolt until they are about one inch from the braces.

It will be noted that about middle ways of each brace there is a small eye bolt. Care must be taken to see that these eye bolts come on the inside side, and also to see that the proper brace is used on the proper side so that the bevel at bottom end of brace fits the cast shoe provided for it on the outside of sills.

Now put together the hoisting apparatus by bolting onto the 4 ft. x 3¾ in. x 1¾ in. oak piece provided, the two iron shoes which are joined onto



two iron rods which in turn are connected onto a ring. Place the shoes on the piece of wood so that the back of the shoes will rest on the ground and act as runners when hoisting the derrick.

Place the ends of the derrick braces in the spaces provided in the shoes. Connect one end of the ¾ in. rope provided for the purpose into the ring of the hoisting apparatus and pass the other end of the rope over the front bolster between the boiler and sill, connecting it to the small hoisting windlass between the sills.

On our Nos. 10 and 12 machines the rope is attached to the worm gear shaft.

One man now go to top of boiler and lift on derrick while one man operates the hoisting crank. After the derrick has been raised about 4 feet from the boiler the man on the crank can easily raise it the remainder of the way.

When the braces have been drawn up close to boiler, take hold of them by hand and set them on the brackets on the outside of the sills. Put the bracket bolts through and set up the nuts securely. Now go to top of derrick and set up nuts at top of braces. After this has been done insert the bolts in bottom of derrick legs and fasten.

The rope guide can now be put in place.

This is done by fastening one end to the derrick by the two bolts provided and then slipping the two rounded ends of the irons into the eye bolts on the braces.

After this guide has been once placed it is never again necessary to unbolt it from the derrick.

When it is desired to lower the derrick simply slide the rods from the eye bolts, swing the guide down next to derrick and tie it there.

On our Traction machines the derrick can be raised without the use of the hoisting apparatus by placing the braces as above instructed at the beginning of the hoisting operation and then backing up the machine. Care must be exercised in doing this, however, to see that the braces are spaced wide enough apart so that the machine does not strike them, and also to see that the lower ends of the braces do not slip on the ground.

## Lowering the Derrick.

In lowering the derrick the operation is as follows:

Loosen the nuts at top of derrick braces, running the nuts back about one inch each.

Slip rope guide out of eye bolts on braces, and, swinging it down, tie it firmly to derrick.

Take out the bolts at bottom of derrick legs.

Take out bracket bolts at lower ends of braces.

Take hold of braces, a man on each brace, and pull on them until derrick begins to swing back.

Now, taking a firm hold on braces, walk back with them as far as possible, being careful not to spread the ends of braces more than 5 or 6 feet apart and also being careful to keep them in line with the machine. When the derrick has been lowered about half way, set the ends of the braces on the ground, and by sliding them out in this manner the derrick can be easily lowered.

When moving the drill from hole to hole, the braces are either laid on top of the derrick and securely roped thereto, or tied onto side of machine.

## Stringing Cable on Machine.

In examining the cable sent out with the machine it will be found, by rubbing the hand back and forth over it, that a nap can be detected.

In placing the cable on machine it is very important that the end of cable which is to be carried up the derrick to place over crown pulley at top is so selected that the nap, when the cable is stroked from the selected end towards the coil, lies flat. By so doing the nap will lie flat when stroked toward the Rope Socket which is to go on the other end.

The reason for this is that the cable does its greatest work when the tools are on the up stroke, and when the tools are being elevated from the hole. Under both of these conditions, owing to the weight being supported by the cable, it is stretched until it is almost as solid as an iron bar, and when it is thus stretched it is much more easily frayed by the sides of the drill hole and by the sheaves over which it travels.

If the cable is put on so that the nap does not lie flat on the upward movement, its action is very similar to cutting against the grain of wood, an action which wears it rapidly.

The proper end of the cable having been selected, carry it up the derrick, place it over the crown pulley at top, from thence pass it over the top of sheave on tail-shaft at lower end of spudder rocker arm, and then passing it UNDER drum, fasten it with the hook-bolt provided, to the side of drum.

In placing cable on drum it is very important that it be passed under the drum, as otherwise it would be necessary to reverse the engine each time the tools were to be raised.

On the Nos. 10 and 12 machines, the cable instead of being passed directly from the crown pulley to the tail-shaft pulley, as described above, is passed from the crown pulley, under the spudder pulley and thence over the tail-shaft pulley. The reason for this is that the Nos. 10 and 12 machines are so constructed that it is never necessary to remove the cable from under the spudder pulley, and thus the cable must be threaded under the spudder pulley when the machine is first strung up.

## Fastening Cable in Socket.

From the end of cable which now hangs from derrick cut off a piece about 4 feet long. This is for use about the machine in cleaning joints, tying on bailer and fastening cable in socket.

The best way to cut Manila cable so that the ends will be even and smooth is to tie cable firmly above point to be cut off, place it on a piece of timber and then with a sharp blow with ax sever it at one stroke.

With each of our regular cable outfits we furnish, unless otherwise ordered, a "Patent Rope Socket" and the method of inserting cable, given below, applies to this kind of socket.

Unscrew the box protector, which to protect the shoulder and threads of box, is screwed into each socket at factory. Stand socket upright with Joint end down. Wrap the end of cable with two or three wraps of small twine and tie it firmly. Insert this wrapped end of cable in top of socket and force it downward until end of cable is nearly through, then turning socket on one side push cable through until about 5 to 12 inches, depending on size of socket, projects beyond.

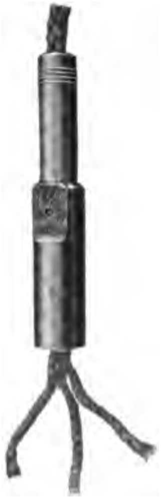


Fig. 4

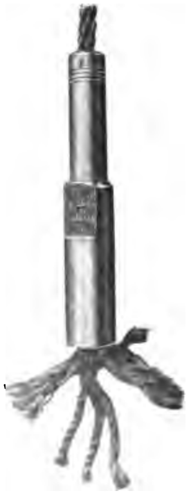


Fig. 5

Unwrap the three main strands of cable back to socket as shown in Fig. 4. Now cut from the 4 foot piece of cable cut off a piece about 10 inches long. Unwrap this short piece until all the strands are separated into the original twine. Even up the ends of this twine. Take a small handful, about 18 to 24 strands, with the ends even and force it up between the strands sticking out below socket, being careful to so place the strands of twine that the same length projects on either side of the cable. Now wrap the main strand under which the twine has been placed one wrap, so that the twine is held firmly as in Fig. 5. Next insert the same amount of twine between the other main strand and the two you have just wrapped. Repeat these operations, using the same amount of twine each time, until the ends of the last twine inserted when smoothed toward the end of cable come out even with the end. This will require the inserting of 3 to 9 (depending on size of socket) bundles of twine, and will leave a space about 4 inches long between the end of the cable and the place where the last bundle of twine was inserted.

Now twist together the three main strands of the cable to the end. Next take several long pieces of twine from the 4 foot piece of cable and wrap the space on the cable below the twine insertions until there are two layers wrapped on, when the ends of the twine used for wrapping should be securely tied. The cable will now appear as in Fig. 6. Now arrange the twine, which is inserted through cable, evenly around cable and smooth it downward towards the end making it as shown in Fig. 7. After this has been done, hold the socket firmly and pull upward on the cable, drawing the cable up into the socket as far as possible. Next, by using the worm gear wind the cable on the drum until the square on socket comes even with the bottom of axle of machine. Place tool wrench on square on socket and shove the head of wrench under the axle. This will leave the handle of wrench projecting out from machine, and this can then be used for prying down, thus forcing the cable into socket. As the cable gradually passes up into the socket take up slack with the worm gear and continue this until the bottom of cable is at least 4 inches from bottom of socket. Next take wrench off socket. To do this it is best to let some slack in cable, as otherwise if the wrench is pulled out from under axle while the strain is on cable, a cracked shin or a twisted arm might result.

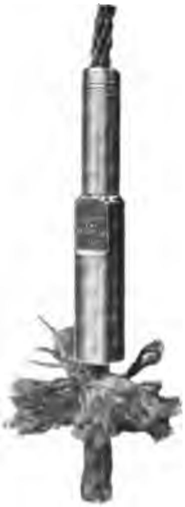


Fig. 6

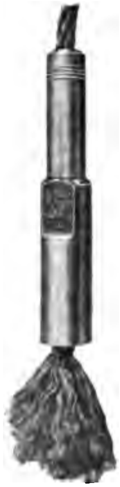


Fig. 7

Next lay socket flat and drive through the two holes (one near top of socket and one through wrench square) the two soft iron pins. Drive the pins completely through until just enough metal projects on the driven side to rivet nicely. Cut off the part projecting and rivet both ends, driving the heads up until they fit snug against socket.

To prevent pins from fraying cable when driven through they should be filed until perfectly pointed and then greased heavily with cylinder oil.

We realize that the above method of inserting cable seems from the description to be very complicated, but in reality it is very simple, and when once understood a cable can be inserted in socket in a few minutes time.

## Removing Cable from Socket.

To remove cable from socket, unscrew the socket from the tools, cut cable on top, drive out pins, and insert socket in the fire, leaving the box end project out so that the fire does not come in direct contact with it.

If the socket is placed in the forge fire, care should be exercised to see that the blast is not too strong, as the socket should be brought to a red heat gradually and evenly. Turn the socket in the fire until cable is nearly consumed, and then by the use of a wooden stick clean it out thoroughly. Allow the socket to cool gradually and under no circumstances place it in water when it is at a red heat, as the steel will crystallize, and there is also liability of the box slightly warping.

## Care of Joints on Drilling Tools.

Before connecting up tools the following instructions on the care of joints should be carefully read:

As the tools come from the factory each box and pin will be coated with a heavy oil and will have plugs and caps screwed into or on them to protect the shoulders and threads. These protectors when not in use on the tools should be carefully preserved, and as soon as a tool is removed from the hole and it is not to be immediately used, the joints should have the protectors placed on them. This is a very important point and should never be overlooked, as a few seconds time spent in adjusting these protectors will often save hours and days of time in fishing jobs.

As we have said, the joints when they arrive will be covered with a heavy oil, and this must all be completely removed. To remove oil from pins, first remove as much as possible with a piece of waste. Next take a piece of Manila twine, removed from the 4 foot piece of cable, insert it between the threads next to shoulder of pin and bend it around the pin until the two ends of twine meet, then holding the two ends with one hand, by a left hand rotary motion revolve the twine around the pin, allowing it to follow the threads until end of pin is reached. The above operation repeated two or three times should thoroughly remove all oil.

The cleaning of the threads in the box is a much more complicated matter, and requires more time, but it is time well spent. As it is impossible to reach the hand up into the box, provide yourself with a small brush with a rather long handle and pretty stiff bristles. The brush should have the bristles placed in the side like a tooth brush, and if it is impossible to obtain any other kind of a brush an old tooth brush may be used and answers the purpose very well.

To clean the box, dip the brush in coal oil and revolve it in the threads. If the oil on the threads is dried and does not start readily, use an old corn cob, revolving it vigorously in the threads. Continue the above operation until the oil is all removed and so that by using a piece of waste the box can be wiped clean and bright.

The shoulders of the joints should now be cleaned and this must be done with even more care than the cleaning of the threads.

Remove all trace of foreign matter from the shoulders and be particular to see that no grease comes in contact with them between the time of cleaning and the time of screwing them together.

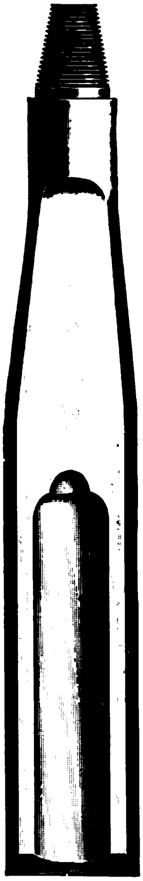
To be absolutely sure that an oil film does not adhere to the shoulders it is best to go over them lightly with a small smooth-grained sandstone, washing them off thoroughly after the operation. It is a good plan to provide yourself with one of these small stones at the very beginning, as the shoulders often require dressing, due to the fact that in setting up the joints they will sometimes roughen up. The proper kind of a stone to use is one that has an absolutely flat surface and one that has a very fine grain. Whenever the shoulders appear to roughen up, grind them until perfectly smooth. Never use a file on shoulders as a file cuts rapidly and there is danger of cutting away more metal than necessary, thus making the shoulder uneven, besides a file leaves file marks and these will have a tendency to cause the shoulders to roughen when setting up the joints.

In taking care of pins on bits, and the box on bottom of stem, a few further precautions are necessary, owing to the fact that these joints are screwed together and unscrewed so often. When the tools are removed from the hole and the joint broken, that is loosened with the tool wrenches, and the bit is unscrewed, the pin and shoulder of bit should be cleaned by pouring clean water over them while the box and shoulder of stem should be wrenched out by flushing water up into it. It will be noted that the water coming off the pin and out of the box has a dark color. This is caused by small particles of the soft steel which have been rubbed from the threads due to the friction in setting up the joints. Unless this very fine steel dust is immediately washed off it will quickly oxidize, some of it adhering firmly to the threads, causing them after a time to set up very hard. This film will also have a tendency to cause the joints to come apart in the hole as it will interpose a surface between the male and female threads, and will prevent them coming snug against each other. All joints on tools as ordinarily sent out are tapered. This is done for the purpose of making the joints stronger, as more metal can be left in the box, and the base of the pin where the greatest strain occurs, can be made larger. It is also possible to more quickly connect and disconnect this style of joint.

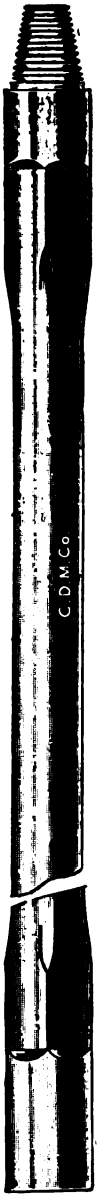
## Connecting Up Tools.

In beginning a hole the drilling tools to be used are Rope Socket, Auger Stem, and Bit.

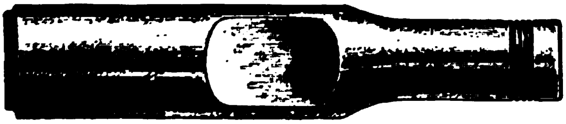
Bit.



Auger Stem.



Rope Socket.

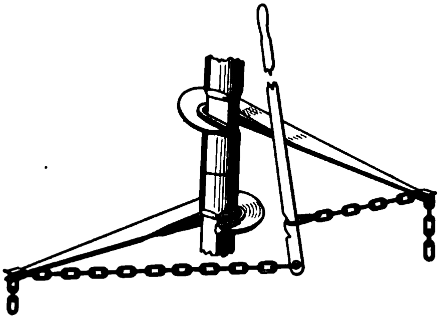


The size and style of bit to be used depends upon the nature and conditions of the drilling, which point will be discussed further on, under instructions for drilling.

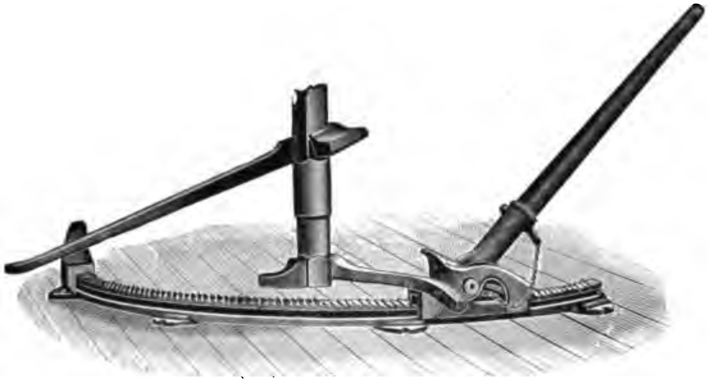
To first connect up the tools, lay the auger stem out in front of the spot selected for the hole, and about 10 feet from it, and, if possible, nearly in line with the center sill of machine. Our reason for so placing the stem is that the tools will be easily hoisted from the ground, as they will come in direct line with machine, thus preventing all side pulls on the Crown Pulley. Place under the round part of stem, between the squares and shoulders of joints, at each end of stem, a piece of timber of sufficient size so that the stem can be raised about 8 inches above the ground, thus allowing sufficient space to use the tool wrenches, as described below. After cleaning joints as directed above, screw the bit into lower end of stem, care being exercised to see that you do not batter the threads or shoulders.

To set up joint tight, put one of the tool wrenches on square of stem. Place the wrench so that the handle comes under stem and projects out to right of it, when you are facing box end of stem. Put the other wrench on the square on flat of bit. Place the bit wrench so that handle comes on top of bit and extends in same direction as wrench on stem. Connect the chain wrenching bar to the wrenches by inserting the links of chain in the claws at ends of wrenches. One man now pulls down on bar and as the joints set closer and closer, one man takes up slack in chain by taking up links.

The accompanying cut shows the action of wrenching bar and will explain its operation without further description, bearing in mind that the cut as shown is to illustrate the manner of setting up joints when the tools are hanging in the derrick.

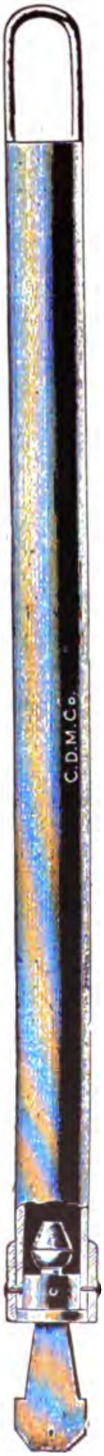


If the joints on tools are 2 x 3 or over, one man may exert his full strength on end of bar without fear of springing threads or twisting off the pin. If the joints are smaller than 2 x 3 it is best to be more careful in the force that you apply. Besides the Wrenching Bar and Chain described above, there are other appliances used for setting up joints, but we have found, for small and for medium sized tools, that the bar and chain are the handiest. On our large outfits we furnish a Forgie or Barrett Jack.



After bit has been set up, next put on rope socket. In putting socket on stem, give the socket several turns in the opposite direction to which it will turn when screwed onto the stem. This will make socket turn on easier and will prevent the cable from kinking.

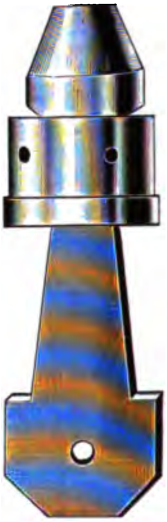
The operation of setting up the socket joint is the same as for the bit, notice being taken that the two joints set up in opposite directions, due to the fact that all threads on cable tools are right handed.



Bailer.

## Bailers.

Dart Valve.



After tools have been connected up, run the sand line onto the sand reel and connect bailer to end of line.

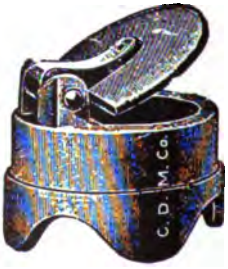
We use a small steel cable for sand line for the reason that a wire line is not only stonger than the small manila lines generally used for this purpose, but also because water will not adhere to the line and thus does not drag from the hole a large quantity of water which will fall upon the drill operator as the line passes over the sand line pulley at top of derrick.

To connect wire line to bailer take a half hitch over bail with line, leaving about two feet of end of line extend out, next take a half knot around line and then tie the end firmly to line with a piece of manila twine.

Bailers as usually furnished are provided with either one of two kinds of valves at bottom.

The valve most usually used is the dart valve which is so constructed that the bailer empties itself when the bailer is allowed to strike the ground.

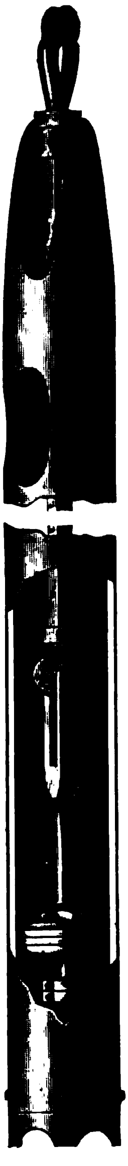
Flat Botton Valve.



The other type of valve is known as flat bottom valve and to empty the bailer it is necessary to set the bailer upon a stake driven in the ground, the stake serving to lift the valve. The advantage of the flat valve is that it provides a larger opening in the bottom of bailer and thus does not clog so easily.

Besides the type of bailer just described there is another type sometimes used, known as the vacuum sand pump shown on following page. As will be noted from the cut, this pump or bailer is constructed with a movable plunger which operates so that a vacuum is produced in the tube as the plunger is pulled upward. This vacuum causes all the cuttings or

Vacuum
Sand Pump.



sludge in the bottom of the hole to be drawn into the tube, completely cleaning the hole.

Vacuum pumps find their most extensive use in mineral prospecting but they are also often used in ordinary well work when large quantities of sand or gravel are encountered. Owing to the suction produced in the pump, it will clean a sandy hole when the other types of bailers are of no account. In fact in some sandy drilling regions holes are drilled with the vacuum pump alone, the drilling tools being used simply for driving the pipe.

## OPERATION OF MACHINE.

### Filling Boiler and Oiling Machine.

If you have to fill the boiler by hand, unscrew the pop valve from boiler, insert the funnel and fill with bucket. If a force pump is available, connect it to the blow-off valve at bottom of boiler, thus making it unnecessary to unscrew pop valve. Fill the boiler until about 3 or 4 inches of water show in the glass. Kindle a slow fire. Do not force fire until about 10 pounds pressure shows, as it is very hard on a boiler to heat it up too rapidly. Especially is this true in the winter time, when the water is extremely cold.

When about 40 pounds pressure shows, turn globe valve at top of boiler which admits steam to steam line. Blow out sight feed lubricator thoroughly, and then fill it with good grade of cylinder oil. After lubricator is ready to start, turn it on until it drops about 4 drops per minute. For the first week or two it is best to also use the grease cup on top of engine, so that the steam chest and cylinder will be sure to have sufficient oil. On cold mornings on starting up machine it is always best to use the cup on engine in addition to the lubricator, as the oil in lubricator is sometimes slow in starting. NEVER ALLOW ENGINE TO RUN UNLESS OIL IS FEEDING TO STEAM CHEST AND CYLINDER. This is a very important point to watch, as lack of lubrication will not only cause rapid wearing of the moving parts in steam chest and cylinder, but the extra duty that it throws on the link and eccentrics wears them rapidly and besides consumes quite a bit of power.

After you have seen to it that the lubricators are working properly, next oil bearings on engine and machine.

Fill all grease cups and screw them down firmly until you are sure that grease is feeding. Put oil in all cups and oil holes, being careful to see, as previously instructed, that the oil is prevented from feeding too fast by the placing of wool waste in bottom of holes.

It would take too much space to describe the position of all oil holes, but all bearings and wearing surfaces are provided with oil holes or places for oil, which should be looked for until found.

Especial care should be exercised to see that all the bearings on engine shaft are fully lubricated, also to see that the Bull or Band wheel shaft has plenty of oil. Probably the most important bearing of all to watch is the crank bearing of engine. You will note that this bearing is lubricated through a hole drilled into the connecting rod. To be absolutely sure that this bearing is receiving a sufficient amount of lubricant, we use a compression grease cup, which at all times keeps a pressure on the grease, thus making its feeding positive. Each of these cups is provided with a screw arrangement at the base of stem by which the feed is regulated.

For the first two weeks after starting the machine an excess amount of oil should be used on all bearings, but after the bearings are once worn smooth, it is possible to greatly reduce the amount used. It is always best, however, to be on the safe side by using rather too much than too little, as oil is much cheaper than machinery.

## Starting Engine.

Drain the main steam line by slightly opening the globe valve on drain line, which connects to steam line, just in front of engine. Next open throttle valve until steam just passes valve. Open wide the drain cocks on cylinder and steam chest, and admit a slightly larger amount of steam at throttle. The condensed water and steam will now blow out of steam chest cock and one of the cylinder cocks. Now reverse the engine, by pulling reverse lever forward. Sometimes, owing to paint or dirt interfering, the reverse lever works very hard. Where this occurs don't try to move lever by throwing all your weight and strength against it. Work it gradually and easily until you see what is causing the difficulty, and then remove the cause. After the reverse lever has been loosened up, work it back and forth, which will admit the steam to both ends of the cylinder, thus warming up all parts of the engine. Now admit a trifle more steam and if engine does not start, take hold of fly wheel and give it a quarter turn. By carefully admitting steam and turning engine, a point will be reached at which engine will start. Do not allow the engine to immediately speed up, as there will still be quite an amount of water in the steam line and steam chest, and if the throttle is opened wide this water will be forced into the cylinder with a rush, and may result in knocking off a cylinder head or the breaking of cylinder rings. An excess amount of water in the cylinder can always be detected by the severe knocking sound which it causes, and when this sound occurs the engine should never be forced rapidly over center, as it puts an excessive strain on all engine parts.

After engine has cleared itself of water close drain cocks.

Now familiarize yourself with the action of throttle and reverse lever. Notice the amount it is necessary to open throttle in order to start engine, and note the increase of speed that follows after opening the throttle different amounts. As there is no governor on the engine, care must be taken to see that the throttle is not opened too wide, as an excess speed of the engine is very harmful to it. The engine can be run with safety up to 400 revolutions per minute, and while it can be run at a higher rate, a very much greater speed is harmful to engine and dangerous to operator. After running engine awhile put on belt which connects engine to band or bull wheel. The easiest method of doing this is to close throttle of engine and then pull reverse lever forward so that engine stands on reverse stroke. If the machine is equipped with our New Clutch, throw the clutch into the central notch, so that neither the hoist nor spudder will be in connection with Band Wheel. If the machine is not equipped with clutch, throw the Sliding Lever to the left, thus disengaging the hoist; also take the spudder pitman off the crank pin, thus disconnecting the spudder from the crank. Put belt on engine pulley, so placing it that only about ⅓ of the width of the belt is on pulley, next lay the belt on top of band wheel, pushing it around and under the wheel as far as it will go. Now by turning the band wheel and pushing against the belt on bottom of wheel with one foot, the belt can be rotated onto the two pulleys. Sometimes, when the belt is extremely tight, it is necessary to rope it to the band wheel and then turn it on.

As the engine is now connected to machine proper, it is necessary, before starting it up, to familiarize yourself with the functions of each of the levers.

## Operating Levers.

We will first consider the machines equipped with shifting levers instead of clutch. On machines so equipped there are four levers and one worm gear wheel, whose positions and functions are as follows:

Sand Reel Lever, on left side of derrick. This lever is for the operation of the bailer, and other purposes. The sand reel is operated by pushing the lever down, which forces the sand reel pulley against the inside of the band wheel rim. The sand reel is held stationary by lifting up on lever, which throws the reel pulley backwards against a wooden brake shoe.

Two Shifting Levers, which are placed between sills with handles extending out to left of worm gear wheel. The top lever, when thrown to the right engages the hoist, and disengages when thrown to the left. THIS LEVER SHOULD NEVER BE THROWN TO THE RIGHT WHEN THE ENGINE

IS IN MOTION, as the gears will be stripped. To engage the hoisting gear, stop the engine and then shift lever. It may be that the gears will not immediately mesh, but by slightly turning the engine by hand a point will be reached at which the lever will shift.

The lower lever is for shifting the worm gear pinion, and before the hoist can be operated must always be thrown out of gear. When drilling is being done, it is always necessary to have the lower gear in mesh, and the upper gear shifted out. This is an easy way of learning the operation of these levers, that is, they must always stand in opposite positions from each other whether hoisting or drilling.

The Worm Wheel is for letting off or taking up slack when drilling, being thrown into and out of action as described.

The fourth lever is the brake lever, at right of machine, and is used for lowering the tools into the hole. When the tools are to be lowered, the brake lever is forced down with sufficient firmness to hold the weight of tools, and then both the hoisting gear and worm gear are thrown out of mesh, leaving the drum free to revolve, as soon as relieved by the band brake.

Now try the operation of these separate levers, going about it slowly and carefully, and being sure before moving either of the shifting levers, that you stop the engine. We would suggest that you also use care in the operation of levers for some little time, until you get accustomed to their action.

If the machine which you are using is equipped with Clutch, there are four levers and one worm wheel, the operations of which are as follows:

One Sand Reel Lever as described above.

One Clutch Lever, which on forward motion throws spudder in action, and which on backward motion throws hoist in operation, and which when in center notch is neutral.

One Shifting Lever for shifting the worm gear pinion.

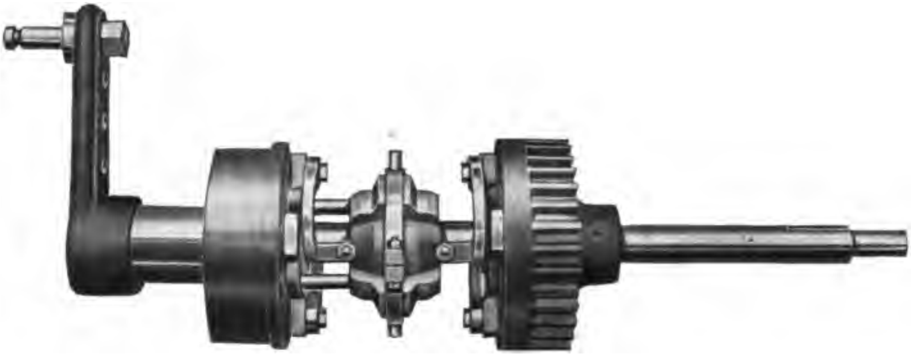
One Brake Band, the same as described above.

The same suggestions made above in reference to trying out levers will apply to clutch machines.

## Cyclone Positive Friction Clutch.

As the clutch which we use on our drilling machines embodies some new features not generally met with, a brief description of its action will be given.

The Clutch is so constructed that both the spudder and the hoisting gear are thrown into action by the moving of one lever. When the lever is pushed into the forward notch the spudder is thrown into action, and when pulled into outside notch the hoist is thrown into gear. When in the center notch the clutch is neutral. As the spudding or crank side of clutch is often subjected to enormous momentary overloads, due to the pulling of pipe or to the tools becoming fast in the hole, no friction clutch of such a size that it could be used on a drilling machine would hold without slipping. The clutch which we use is provided with an automatic positive attachment, which, when a momentary overload occurs, and the clutch starts to slip, causes two tool steel pins to engage in holes provided for them, thus locking the clutch and making it positive. The action of these pins is entirely automatic, and when it is desired to stop the spudder, the pins are released by the same lever which releases the friction part of clutch. The pins are so placed, and their operation is such, that there is absolutely no chance for the clutch to take hold violently, as the friction shoes always engage first, when the clutch is set up, and disengage last, when the clutch is released. It will be noted that a double cone operates both crank and hoist side of clutch, the wear being taken up by adjusting screws. It will be noted that there are four of these adjusting screws, two being for use on each clutch. To set up either of the clutches tighter, release the two adjusting screws, which operate the clutch to be set up, by loosening the jam nuts. Screw the two adjusting screws down about one-half turn, and then try clutch. If it is still too loose, try another half turn, always being careful to see that both adjusting screws are set up exactly the same amount. After the screws have been set up the proper amount screw the jam nuts down firmly.



Cyclone Positive Friction Clutch.

The clutch is provided with oil holes at different points and two grease cups. One grease cup is screwed into hub of crank, and the other in top of the clutch ring which passes around the cone. The clutch should be thoroughly oiled, care being exercised to see that sufficient oil is used on the faces of the friction shoes to prevent them from cutting when the clutch is running idle. There is an oil hole on the external hub of hoisting gear of clutch, that, unless looked for carefully, may be missed, and as it is very important that this bearing be oiled, we are calling particular attention to it. Owing to the fact that the hub of gear extends out over sill of machine, we are unable to use oil or grease cups, and have, therefore, drilled hole into hub, into which is screwed a set screw. Into the bottom of this hole place a little wool waste, then fill with oil and screw in set screw.

## Drilling Operations.

The action of the engine and different levers now being understood, you are ready to begin drilling operations.

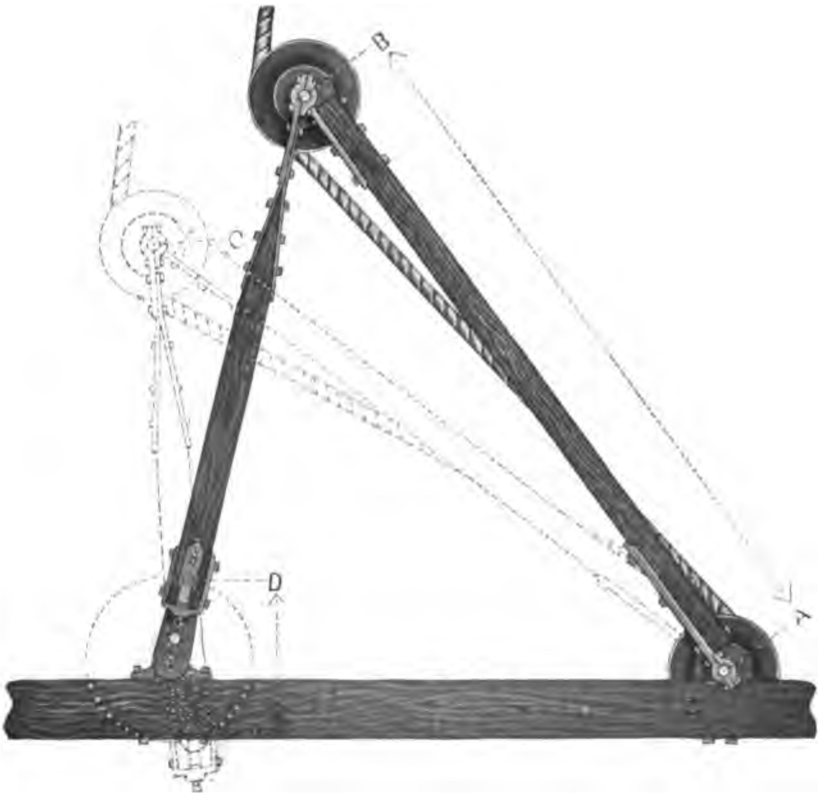
Throw hoist into gear, and hoist the drilling tools until "they hang in the derrick." Allow tools to hang free and mark spot directly beneath. If the start is to be made in soil, dig a hole about 2 feet deep and just a little larger than the hole to be drilled. Some drillers use a post hole digger for starting, digging down about 2½ to 3 feet with it. In starting the hole care should be exercised to see that the hole started comes in direct line with the tools, when they are hanging free. This point is very important, for if the hole is not in direct line there will be a constant tendency for the tools to drift off, making the hole crooked.

Lower the tools into the hole by using the brake. Now by letting slack into the cable, swing the top of tools over, until they rest against derrick. Now place spudder pitman, on crank pin, if same is not already on. Next, by giving the engine steam and regulating its action with reverse lever, swing the spudder crank around until the crank is at its highest point, thus throwing the spudder to the limit of its up stroke. This is what drill men call centering the crank, and after a little practice in the handling of the engine, you will be able to center the crank the first time over. Now have your helper place drill cable under the spudder sheave. After cable is under sheave, throw the worm gear in mesh, and take up slack in cable. Take up the slack until the tools are lifted about ½ inch from bottom of hole. You will find for the first few days that the worm gear and all shifting levers work rather stiff, due to the presence of paint and varnish on them, but if they are kept liberally supplied with oil they will soon move free and easy.

Now have your helper go up the derrick until he is about even with top of tools, where he should station himself to assist in steadying the tools. Next see that your worm gear is in, and all other gears are out. Turn steam to engine. You will note that at first engine will not pull crank over lower center, unless the throttle is open very wide. If enough steam were turned on to force the spudder directly over, the amount would be sufficient to give excess speed to the engine, and as it is necessary that the tools be run at a slow rate, until the hole is at least 5 or 6 feet deep, the engine should be started as follows:

Admit enough steam to pull the crank about one-half the way down. When the crank reaches this point immediately reverse the engine. The effect of this will be to lift the tools a little more than one-half on the back stroke. When the crank reaches the farthest point to which it will go on the back stroke, quickly push the reverse lever to forward motion again. You will observe that the weight of the tools on this motion will assist the the engine in speeding up and passing lower center. Keep repeating these motions, admitting a slightly larger amount of steam each time, until finally power enough is stored up to start the spudder into continuous motion.

After once becoming familiar with the action of the engine, you will find no difficulty in starting it on one motion of the reverse lever.



The motion of the Spudder when drilling should always be forward. That is, when standing at the side of machine opposite to that on which the big band wheel is placed, and facing the machine, the crank should revolve from right over to left. This motion gives a powerful lift and an extremely quick drop.

As the proper understanding of the theory of the Cyclone Spudder has much to do with successful drilling, and the successful pulling of pipe, we will devote a few words to the spudder itself.

The cut on preceding page shows the spudder at both its extreme up stroke and its extreme down stroke. You will notice that as the spudder crank moves from D to the left and down that it does not begin to ascend until after it is about ⅓ past the lower center, which is opposite D. The result of this is that the travel of the spudder crank pin is much less from its extreme low point to its extreme high point, than it is from its extreme high point to its extreme low point. It is due to this arrangement that we get our extremely quick drop. The action of the spudder is such that the tools are gradually lifted as the spudder passes from D around and about ⅓ of the way past center opposite D, then the spudder is quickly lifted as it travels from the low center to D, giving the tools an absolutely unimpeded fall. This is the famous Cyclone Spudding stroke. Now if the engine is reversed and the spudder run in the opposite direction, its action is just the reverse of the foregoing. That is, the down stroke of the spudder is made in much less time than the up stroke, thus delivering a strong upward jerk on the tools.

To satisfy yourself that the spudder action is as stated above, before putting the drilling cable under spudder sheave, start the engine and run the spudder about 40 strokes per minute on both the forward and reverse motions. So pronounced is the difference between the two strokes that it is readily discernable to the eye.

It will be explained later, the methods to pursue when pulling pipe with the pipe puller, and also the method to pursue when loosening tools by driving with the jars, and both these methods depend upon this feature of the spudder.

There is another excellent feature contained in the Cyclone Spudder, and that is its action in regard to the drilling cable. You will note that the cable is so arranged in respect to the spudder sheave that there is absolutely no backward or forward travel of the sheave on the rope. The sheave is simply a point of contact for bending the rope down while the spring underneath the sheave lifts the rope back. This feature of the Cyclone Spudder accounts for the long life of all Cables used on Cyclone machines.

Now to return to the drilling.

If the soil in which the drilling starts does not contain a large percentage of clay, the hole can be spudded down quite a way without placing any water in it, the action of the tools forcing the dirt out into the sides of the hole.

Where this method of starting can be followed, it is always best to use it, as it makes the hole more firm and does away with the necessity of bailing. When a point is reached where the dirt will not pack into the walls, pour water into the hole. In average soil it requires from 2½ to 4 gallons for each foot drilled.

After the sludge has become about as thick as a thin batter, pull the tools and bail out.

Never run the tools until the sludge becomes so thick that the tools do not fall clear, as, under this condition, the bottom of the hole will be filled with a thick sludge, which will stop up the bailer, and which will consume much time in bailing out. Much better time can be made by bailing out often, thus preventing the accumulation of heavy sludge.

Another reason for bailing often is that a heavy sludge prevents the tools from turning readily, and as the tools must be turned constantly when drilling in soil, it is necessary that no condition be allowed to arise which will prevent this.

## Turning the Tools.

As will be noted, the edge of the bit is a straight line, and the bit, when properly dressed, fills about 1/6 to 1/4 the circumference of a circle.

If the tools were allowed to drill ahead without turning, the hole would be cut about the shape of the bit, and would result in what drillers call a "flat hole." To prevent this, when drilling in soil, the tools are constantly turned by hand, first swinging the tools in one direction and then swinging them in the opposite direction.

After the rope socket has passed below the surface the tools are turned by twisting the cable. It will be noted that as the tools are lifted and their weight supported by the cable, it becomes about as rigid as an iron bar, and if the cable is twisted when in this condition, the twisting effect is transmitted directly to the tools, even if they are several hundred feet below the surface.

An experienced drill man is able to tell by giving the cable one twist whether or not the tools are turning, but for beginners, until they have learned the "feel of the cable," we would recommend, in order that they may be sure the tools are turning, that they twist the cable 4 or 5 times, to the right, then let the cable loose and see if the tools turn back as the cable twists back. If the tools are not turning with the cable, the cable will twist back instantly, but if the tools are turning with the cable, the cable will twist back slowly, the rate of the return of the tools depending upon the amount and thickness of sludge and water in hole.

Some drillers use a rope handle for twisting the cable. A rope handle is a device made for clamping to the rope, and is provided with a handle from 1½ to 2½ feet long, so arranged that the cable can be easily twisted.

When solid rock is reached it is unnecessary to turn the tools by hand, as the blow which is struck by the bit has a tendency to turn the tools. This fact can be proven by taking a firm hold on the cable when drilling in rock, and noticing the twisting action which the rope undergoes after each blow. Sometimes, when the rock is full of joints and crevices, it is necessary to turn the tools by hand, as the bit will have a tendency to follow the path of least resistance, and unless turned a flat hole may result. This condition will be discussed further on.

## Driving Pipe.

If the soil in which the drilling is being done is of such a nature that the hole "stands up" without casing, the hole can be spudded down 20 or 30 feet before setting in the pipe. If coarse gravel is encountered, or for any other reason, the hole shows a tendency to cave, it is necessary to insert pipe. The length of pipe to be used depends upon the depth which it is possible to drill the hole before it caves. If the hole is 15 feet or more in depth use a joint of pipe 18 to 20 feet long.

As a hole is usually started with a spudding bit, and as the spudding bit is always dressed out to a size about ½ inch larger than the outside diameter of the couplings on the pipe used, the first length of pipe can be lowered into the hole and will not require any driving. If, however, a bit the size of the internal diameter of the pipe is used, and this is often the case, it will be necessary to drive the pipe to get it to the bottom of the hole.

If the bit used to start the hole is larger than the internal diameter of pipe, it is now necessary to unscrew this bit from stem and substitute a bit which will go inside the pipe.

To use the wrenching bar and chains for loosening and tightening the joints when the tools are hanging in the derrick, the wrenches and bar are arranged as shown on page 15. The cut shows the wrenches arranged for tightening the joint.

For loosening joint the wrenches are just reversed, that is, the wrench shown on lower square is placed on upper square, and the upper wrench is placed on lower square.

A good heavy stake is driven into the ground, against which one of the wrenches is allowed to strike, to prevent the wrenches from swinging around.

When a platform is used around the hole a block can be nailed to platform and answers the same purpose as the stake.

Some drillers use the sand line for handling pipe, and when joints 4 to 8 feet in length are used, and the pipe is not over six inches in diameter, this plan can be safely used; but when full length joints are used the pipe can be more easily and safely handled by slipping the pipe on stem. Not only is this method safer, but it has the advantage of always keeping the pipe in line with the hole, thus making the threads start more easily when joints are to be secured together.

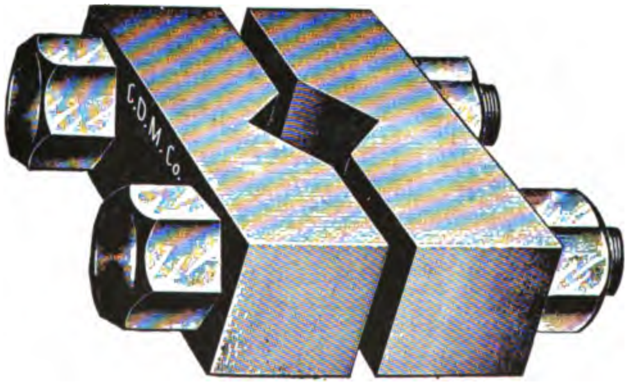
After having placed proper size of bit on stem, lay the tools on ground, out past the hole, and in line with the machine. If the string of tools are for drilling holes 3½ to 4½ inches in diameter, the tools can be lowered by helper taking hold of tools just at top of bit and carrying them out as the driller lets off slack.

If the tools are of such size that one man cannot lift one end of them, they can be lowered by use of the firing shovel. The way to use shovel is to swing the tools out as far as possible and then lower them until bit rests on shovel blade, so placing shovel that handle extends outward from machine. Now let slack in cable until top of rope socket just clears derrick, when the tools can be lowered by pulling on shovel, thus sliding out lower end of tools.

As the end of tools is pulled further and further outward, it is, of course, necessary to let out more slack in cable. Some drillers use a small cart, called a "dollie," for handling the tools, but for tools of ordinary size the shovel will answer every purpose, and has the advantage of being light and not adding any extra weight to the equipment.

When the tools have been pulled outward far enough so that the rope socket will clear the machine, lower the tools until the middle of the tools is about 2 feet from the ground, then place an 8 or 10 inch block under tools so that when they are completely lowered they will balance over block.

Next place the clamp on square at top of stem. If you are drilling inside of pipe it is easier to place the clamp on tools before laying them on the ground; but for the first joint time and energy can be saved by placing clamp after lowering the tools.



You will note from illustration that clamps are constructed with a space cut back in each block. These spaces are made to fit the squares on stem, and the blocks should be so placed that the top of clamps fits snug against the shoulder at top of squares.

You will note that we say to place clamp on square on stem. It is sometimes necessary when an extra long piece of pipe is being used, to place the clamps on the square on rope socket so as to give space between top of pipe and crown pulley for a stroke to the tools, but it is best to place clamps on square of stem if possible, as otherwise the threads of the pin on stem will have to stand the full strain of the driving blows.

Be sure to see that clamps fit snug against shoulder of square, then draw up nuts on clamp bolts firmly.

After tightening up clamps lower tools until they balance over block so that the bit end of tools clears the ground by about 8 inches. You are now ready to slide pipe onto tools.

One man get at each end of pipe and holding it in line with drilling tools, slip it on tools until the pipe strikes the block over which the tools are balanced.

Next take up slack in cable until the tools are lifted clear of block, and until the end of pipe which is on the tools clears the ground about a foot. Now move the block back far enough so that when the tools are again lowered, the end of pipe which is on the tools will be supported on block. Lower the tools, let slack in the cable, and by taking hold of clamp on tools push the tools down into the pipe until the clamps strike top of pipe. Fasten the pipe securely to the stem by roping or chaining it to the clamps.

If the length of the drilling tools between end of bit and botton of drive clamps is greater than the length of pipe used, it will be necessary to slide the tools down the pipe, as instructed above, until the end of bit extends through pipe. Then take up slack in cable until the weight of tools is supported by the cable and end of bit, when the pipe can be slid up the stem until it comes against clamp.

After fastening pipe securely to stem, hoist the tools until they hang in line with hole. Now let off slack, lowering the pipe and tools into hole. When a point is reached where the pipe refuses to go any further, try twisting it slightly with the chain tongs.

Care must be exercised when twisting the pipe to see that the brake is held firmly, as otherwise, if the pipe should suddenly start with the full weight of tools above it, the pipe tongs might be wrested from the operator's hands, resulting in serious injury.

If the pipe refuses to go down after twisting, take off the fastenings which hold it to the clamp, place cable under spudder sheave and take up slack in cable until the drive clamps are lifted about 2 inches above top of pipe. Now start engine slowly, putting spudder into motion the same as when drilling. Regulate the stroke of the tools so that the clamps just strike top of pipe, letting off slack as pipe goes down.

Do not run the spudder over 35 strokes a minute unless the pipe has a tendency to drive hard, when the engine can be speeded up, thus producing a much heavier blow.

Continue the driving until the top of pipe comes within about one foot of the ground or at least until the lower end of pipe reaches the bottom of the hole. It may be that the hole is not deep enough to take the full length of pipe without leaving several feet extend above ground. If such is the case, try to drive the pipe far enough so that there will be sufficient space between top of pipe and the crown pulley for the tools to be drawn from the hole.

It is always considered rather risky practice to drive pipe ahead of the hole, and unless the pipe drives easy, it should not be attempted.

The reason for this is that a large boulder might be struck which would cause the pipe to glance off, thus causing a slanting hole, or else the pipe might strike the boulder fair enough to crimp the end of pipe.

## Protecting Pipe for Driving.

You will note that in the above instructions on pipe driving we have said nothing about the precautions it is necessary to take in order to protect the ends of pipe while being driven.

We have intentionally omitted these instructions until now as the subject is so important that it should be treated separately.

As the soil through which the pipe must be driven may be full of boulders or may contain layers of gravel, cemented into hard pan, or other obstructions may be encountered, and as it is necessary to force the pipe past these obstructions, some protecting device must be placed on the lower end of pipe which will prevent the pipe from collapsing or crimping on the end.

If the nature of the material above bed rock is pretty well understood, and it is known that not a great many boulders will be encountered, or that no heavy bands of hard pan will have to be passed, then an ordinary pipe coupling such as comes with the pipe can be used, and will answer the purpose fully as well as any other device.

If coupling is to be used and the amount of pipe necessary to use to reach bed rock is over 50 or 60 feet, or if a great amount of sand or gravel are to be driven through, then the coupling should have the following change made in it:

You will note that the metal on each end of a coupling rounds outward from the inside. If the end of the coupling was left in this shape it would form sort of a wedge against the side of the hole and would drive very hard, especially if sand were encountered, or if it were necessary to drive through bands of soapstone or very firm clay.

To prevent this wedging action, cut the end off of coupling far enough back so that the end comes square with side. Of course it is only necessary to cut off one end as the other end will be screwed onto the pipe. After end has been cut off, bevel the coupling from the inside outward, making the bevel at an angle of about 50 degrees. This work can be best done on a lathe.

You will note that a coupling so shaped will cut a clean hole and will have no tendency to wedge in the hole, as the sides of the bore hole, as pipe is driven, will be forced into the inside of pipe by the action of the bevel.

Some drillers cut a coupling in two in the middle and then use half of coupling for driving purposes, but if the amount of pipe to be driven is over 50 or 60 feet it is best to use a full coupling. In screwing the coupling on pipe, it should be screwed on as far as possible as the greater the number of threads meshed, the greater amount of driving the coupling will stand.

The threads on pipe and coupling should be carefully inspected before screwing together, and if any dirt should be present it should be removed, or if there are any smashed threads they should be filed until smooth.

A plentiful supply of oil in the threads will greatly assist in the operation of setting up the coupling. After the coupling is screwed on, the pipe should be carefully examined to see that no rough edges extend out into pipe as these rough edges if allowed to remain will come in contact with drilling cable and will wear it rapidly.

In this respect we wish to add that all pipe used should be carefully examined for flaws and obstructions, not only at the threads but for the full length of the pipe.

Look carefully, not only on the outside, but on the inside of the pipe. It sometimes happens that through some error in making, the metal in the pipe was not evenly distributed, leaving a very thin wall at some points.

If a pipe so constructed is allowed to go into the hole it is very liable to collapse under hard driving, and if this occurs it will be necessary to pull the pipe, and if it is impossible to do this will result in the loss of the hole and all the pipe which is in it.

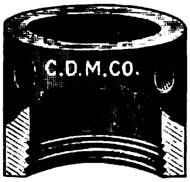
If the material through which the pipe is to be driven is full of heavy boulders, or if hard bands are encountered, the protecting coupling used above will not prove adequate to protect the end of the pipe, and it is then necessary to use a specially constructed protector called a drive shoe.

These protectors are made of steel, tempered, and are so constructed that heavy driving can be done without fear of injuring the end of the pipe. The top of drive shoe is cut out, forming a sleeve, which fits up snug along the side of the pipe, protecting it from all side strains which have a tendency to strip the threads. The threads begin at base of sleeve and are cut down to within about 1½ inches of bottom of shoe. At the base of thread there is a shoulder which comes against the bottom of pipe which thus transmits the full force of the blow from shoe to pipe without its falling upon the threads.

Drive shoes are made in all sizes and can be furnished with threads to fit either drive pipe or casing.

The lower end of pipe being taken care of, it is now necessary to con-consider the upper end of pipe on which the driving blows are delivered by the driving clamp. If the amount of pipe to be driven does not exceed 50 to 60 feet, and no heavy driving will be encountered, a coupling can be used, taking it off after each piece is driven and putting it on the next piece to be driven, thus battering up but one coupling.

If, however, much pipe is to be driven, or heavy driving is to be done, it is much better to use a regular drive head.



A drive head is made of steel and is so constructed that the end of pipe when screwed into the head comes against a shoulder, and thus the blow falls directly upon the end of pipe without straining the threads.

The top of drive head being made thicker than ordinary couplings and being made of steel, also stands much more driving without battering and thus furnishes a smooth bore for the cable to work through while drilling.

Drive heads are made in all sizes and can be furnished with threads to fit either drive pipe or casing.

## Kinds of Pipe Used in Well Drilling.

Pipe, as now furnished to the trade, is made of either wrought iron or steel. Years ago, before the Bessemer process of steel making was extensively used, all pipe was made of wrought or puddled iron. Owing to the fact that steel can be produced more cheaply than wrought iron, steel pipe, for all ordinary purposes, is now almost universally used. In fact, steel pipe is the only kind carried by many pipe jobbers, and wrought iron pipe can be obtained only by specifically stating when ordering, that "This pipe must be Wrought Iron Pipe."

There is now being put on the market, by the steel manufacturers, a brand of pipe called Wrought Pipe, and while this pipe is often furnished by jobbers for Wrought Iron Pipe, there is absolutely no wrought iron used in its making. We cannot see the reasons of the steel makers for introducing this name into the pipe business, as it has resulted in much confusion in the classifying of pipe.

Steel pipe possesses a much higher tensile strength than wrought iron, and when the pipe is to be used for carrying high pressure, and when it is to be placed so that it will be protected from the weather, it is to be preferred to wrought iron. For casing wells, however, the wrought iron possesses advantages over the steel for the three following reasons:

1. Owing to its fibrous character wrought iron is tougher than steel, and the pipe will stand much harder driving. Steel pipe, under heavy driving, seems to crystallize ,and often breaks off at root of threads just at top of coupling. Steel pipe also has a tendency to bulge at couplings when subjected to hard driving.

2. Wrought iron pipe, when placed in the ground, or exposed to the weather, will last much longer than steel pipe. This point has been proven by hundreds of oil men throughout the country by examinations of casing

which has been removed from oil wells, after having been in the ground for years. Wrought iron pipe almost invariably comes out in good shape, while the steel pipe is deeply pitted, and in many cases is so badly rusted as to be worthless.

The writer is unable to give any certain reason for the more rapid rusting of steel, but the theory advanced by metallurgists is, that the greater resisting qualities of wrought iron are due to the fact that the fibres of wrought iron are encased in thin layers of a silicious slag, which entered while the iron was being puddled, and which prevent the rusting agencies from coming in direct contact with the iron.

3. More perfect threads can be cut on wrought iron than on steel pipe, and as the wrought iron is much tougher than steel, the threads will stand much heavier driving without stripping.

Pipe as ordinarily used for drill work is listed under three heads:

## Merchant Pipe, Casing, and Drive Pipe.

**Merchant Pipe**—This term is used to indicate the regular pipe of the market, and such orders are usually filled by the shipment of soft wrought steel pipe. The weight of merchant pipe will usually be found to be about 5 per cent. less than card weight, in sizes ⅛ inch to 6 inches, inclusive.

Merchant pipe is made in sizes ranging from ⅛ in. to 16 in. inclusive.

From ⅛ in. up to 1½ in. the pipe is butt welded. Larger sizes are lap welded. The number of threads per inch of screw varies for the different sizes, up to and including 2 in., but all threads on pipe above 2 in. are cut eight to the inch.

As Merchant Pipe is designed to be used for carrying internal pressure, the threads are cut on a taper, so that as the pipe is screwed into the coupling, the metal of pipe and the metal of coupling will be drawn closer and closer together. While this style of thread will stand good hard driving, it is not so safe as the threads cut on regular drive pipe, which point will be discussed under drive pipe.

By reference to the cuts of joints given on page 33, it will be noted that with this style of connection the ends of pipe do not meet in the coupling, so that when the pipe is being driven the full force of the blow falls upon the threads.

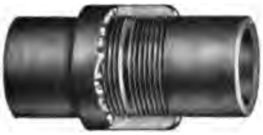
Merchant Pipe can also be furnished with couplings having long sleeves projecting above the threads.

This sleeve is formed by using a long coupling and then recessing a space into ends of coupling. The threads begin at end of recess, and when the coupling is screwed onto pipe the sleeve fits snug along the side of pipe, thus protecting the threads from all side strains.

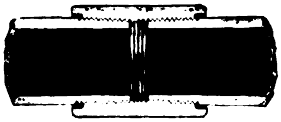
Sleeve couplings are not regularly furnished with the merchant pipe, and will not be sent unless the order specifically calls for them. A small extra charge, above the regular coupling price, is usually made for them.

The table on following page gives the various weights and dimensions of merchant pipe.

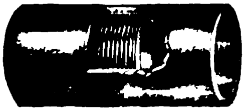
## Illustrations of Couplings and Joints used on Various Kinds of Pipe.



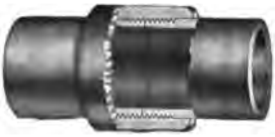
Line Pipe—Coupling Joint.



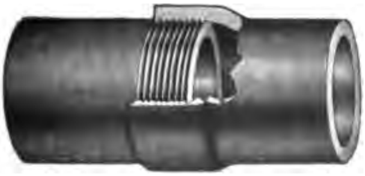
Merchant Pipe—Coupling Joint.



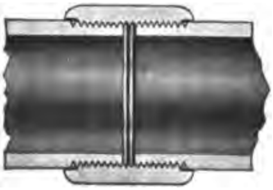
Drive Pipe—Flush Joint.



Drive Pipe—Coupling Joint.



Inserted Joint for Casing.



Coupling Joint for Casing.

# Wrought Iron and Steel Welded Pipe.

## Dimensions, Weights, Etc., of Standard Sizes for Steam, Gas, Water, Oil, Etc.

| Inside Diameter | Outside Diameter | External Circumference | Length of Pipe per sq. foot of Outside Surface | Internal Area | External Area | Length of Pipe containing one cubic foot of surface | Weight per foot of Length | No. of Threads per inch of Screw | Contents in Gallons per foot | Weight of Water per foot of Length |
|---|---|---|---|---|---|---|---|---|---|---|
| Inches | Inches | Inches | Feet | Inches | Inches | Feet | Lbs. | | | Lbs. |
| ⅛ | .40 | 1.272 | 9.44 | .057 | .129 | 2500. | .24 | 27 | .0006 | .005 |
| ¼ | .54 | 1.696 | 7.075 | .104 | .229 | 1385. | .42 | 18 | .0026 | .021 |
| ⅜ | .67 | 2.121 | 5.657 | .191 | .358 | 751.5 | .56 | 18 | .0057 | .047 |
| ½ | .84 | 2.652 | 4.502 | .304 | .554 | 472.4 | .84 | 14 | .0102 | .085 |
| ¾ | 1.05 | 3.299 | 3.637 | .533 | .866 | 270. | 1.12 | 14 | .0230 | .190 |
| 1 | 1.31 | 4.134 | 2.903 | .862 | 1.357 | 166.9 | 1.67 | 11½ | .0408 | .349 |
| 1¼ | 1.66 | 5.215 | 2.301 | 1.496 | 2.164 | 96.25 | 2.25 | 11½ | .0638 | .527 |
| 1½ | 1.9 | 5.969 | 2.01 | 2.038 | 2.835 | 70.65 | 2.69 | 11½ | .0918 | .760 |
| 2 | 2.37 | 7.461 | 1.611 | 3.355 | 4.430 | 42.36 | 3.66 | 11½ | .1632 | 1.356 |
| 2½ | 2.87 | 9.032 | 1.328 | 4.783 | 6.491 | 30.11 | 5.77 | 8 | .2550 | 2.116 |
| 3 | 3.5 | 10.996 | 1.091 | 7.388 | 9.621 | 19.49 | 7.54 | 8 | .3673 | 3.049 |
| 3½ | 4. | 12.566 | .955 | 9.837 | 12.566 | 14.56 | 9.05 | 8 | .4998 | 4.155 |
| 4 | 4.5 | 14.137 | .849 | 12.730 | 15.904 | 11.31 | 10.72 | 8 | .6528 | 5.405 |
| 4½ | 5. | 15.708 | .765 | 15.939 | 19.635 | 9.03 | 12.49 | 8 | .8263 | 6.851 |
| 5 | 5.56 | 17.475 | .629 | 19.990 | 24.299 | 7.20 | 14.56 | 8 | 1.020 | 8.500 |
| 6 | 6.62 | 20.813 | .577 | 28.889 | 34.471 | 4.98 | 18.76 | 8 | 1.469 | 12.312 |
| 7 | 7.62 | 23.954 | .505 | 38.737 | 45.663 | 3.72 | 23.41 | 8 | 1.999 | 16.662 |
| 8 | 8.62 | 27.096 | .444 | 50.039 | 58.426 | 2.88 | 28.34 | 8 | 2.611 | 21.750 |
| 9 | 9.68 | 30.433 | .394 | 63.633 | 73.715 | 2.26 | 34.67 | 8 | 3.300 | 27.500 |
| 10 | 10.75 | 33.772 | .355 | 78.838 | 90.792 | 1.80 | 40.64 | 8 | 4.081 | 34.000 |

**Casing**—Casing is a kind of pipe which the needs of the oil well business brought into the market. It is made in many sizes not found in standard pipe, and nearly all sizes above 4 inches are made in several weights, so as to cover the varying needs of the oil well business.

Casing is designed to be used for casing off water or other troublesome material, which may be encountered after the drive pipe has been seated in the rock, and is not intended for heavy driving.

For ordinary water well work, however, it may be driven, if the heavier grades of casing are used. We do not recommend that it be used, if a long line of pipe has to be driven, as both merchant pipe and drive pipe will stand much heavier driving.

There are three styles of joints used in casing: The "Socket Coupling," the same as used on Merchant Pipe, only with finer threads, the "Inserted Joint," and the "Flush Joint."

INSERTED JOINT—The Inserted Joint is made by cutting a thread on one end and expanding the other, and cutting in it an interior thread, so that the end of one piece screws into the end of another. Casing with this style of joint should not be driven.

The Inserted Joint, while somewhat smaller in external diameter than a regular coupling joint, is yet larger than the Flush Joint.

FLUSH JOINT—The Flush Joint on casing is made by cutting interior and exterior taper threads on the ends, so that the end of one piece will screw into the other.

Flush Joint Casing has the same inside and outside diameters at the joints as at other places, so that it is perfectly flush, both inside and out, thus permitting the use of the largest possible casing inside of a pipe of given size.

As Flush Joint Casing, owing to the joints, is not strong, it should be handled with great care.

The table on following page gives the various weights and measurements of casing of different sizes.

**Drive Pipe**—Drive Pipe is made of either merchant pipe, full weight pipe, extra strong pipe, or double extra strong pipe.

Standard Drive Pipe is made of same weight stock as merchant pipe, the difference between merchant pipe and drive pipe being in the kinds of threads and couplings used.

Owing to the fact that drive pipe is intended for driving purposes only, the threads are cut straight, so that the ends of pipe meet or "butt" in the center of the coupling.

By the use of this kind of joint, the force of the driving blow does not fall entirely upon the threads, and thus the danger of telescoping is reduced as much as possible.

# Wrought Iron and Steel Casing.

| Nominal Inside Diameter | Outside Diameter | Nominal Weight Per Foot | No. of Threads per Inch of Screw | Outside Diameter of Couplings |
|---|---|---|---|---|
| Inches | Inches | Pounds | | Inches |
| 2 | 2¼ | 2.16 | 14 | 2.687 |
| 2¼ | 2½ | 2.75 | 14 | 2.875 |
| 2½ | 2¾ | 3.04 | 14 | 3.187 |
| 2¾ | 3 | 3.33 | 14 | 3.500 |
| 3 | 3¼ | 3.96 | 14 | 3.781 |
| 3¼ | 3½ | 4.28 | 14 | 4.000 |
| 3½ | 3¾ | 4.60 | 14 | 4.250 |
| 3¾ | 4 | 5.47 | 14 | 4.625 |
| 4 | 4¼ | 5.85 | 14 | 4.687 |
| 4¼ | 4½ | 6.00 | 14 | 4.937 |
| 4¼ | 4½ | 9.00 | 14 | |
| 4½ | 4¾ | 6.55 | 14 | 5.218 |
| 4½ | 4¾ | 9.00 | 14 | |
| 4¾ | 5 | 7.58 | 14 | 5.562 |
| 5 | 5¼ | 8.00 | 14 | 5.781 |
| 5 | 5¼ | 10.00 | 14 | |
| 5 | 5¼ | 13.00 | 11½ | |
| 5 | 5¼ | 17.00 | 11½ | |
| 5 3/16 | 5½ | 8.40 | 14 | 6.062 |
| 5 3/16 | 5½ | 13.00 | 11½ | |
| 5⅝ | 6 | 10.16 | 14 | 6.625 |
| 5⅝ | 6 | 12.00 | 11½ | |
| 5⅝ | 6 | 14.00 | 11½ | |
| 5⅝ | 6 | 17.00 | 11½ | |
| 6¼ | 6⅝ | 11.50 | 14 | 7.125 |
| 6¼ | 6⅝ | 13.00 | 11½ | |
| 6¼ | 6⅝ | 17.00 | 11½ | |
| 6⅝ | 7 | 12.45 | 14 | 7.687 |
| 6⅝ | 7 | 17.00 | 10 | |
| 7¼ | 7⅝ | 13.50 | 14 | 8.220 |
| 7⅝ | 8 | 15.00 | 11½ | 8.625 |
| 7⅝ | 8 | 20.00 | 11½ | |
| 8¼ | 8⅝ | 16.00 | 11½ | 9.312 |
| 8¼ | 8⅝ | 20.00 | 11½ | |
| 8¼ | 8⅝ | 24.00 | 8 | |
| 8⅝ | 9 | 17.50 | 11½ | 9.750 |
| 9⅝ | 10 | 21.00 | 11½ | 10.812 |
| 10⅝ | 11 | 23.00 | 11½ | |
| 11⅝ | 12 | 25.15 | 11½ | |
| 12½ | 13 | 35.75 | 11½ | |
| 13½ | 14 | 38.82 | 11½ | |
| 14½ | 15 | 42.00 | 11½ | |
| 15½ | 16 | 45.10 | 11½ | |

To get this result, however, it is necessary that the pipe be screwed into the coupling until the ends meet. To be absolutely sure that the ends "butt," it is best to count the number of threads between end of pipe already in the coupling, and the last thread in coupling, and then by counting an equal number of threads on the end of pipe to be inserted, it can be told with absolute certainty whether or not a correct union is being made.

When extremely severe driving has to be done, it is best to use drive pipe made from full weight pipe, extra strong pipe, or double extra strong pipe.

The last two kinds are seldom used, except under special conditions, owing to their high cost, but the full weight pipe is extensively used, when long lines of pipe must be driven through bouldery ground.

The term "Full Weight Pipe" is used for pipe which is above card weight. All such pipe is made from plates which are expected to produce pipe of card weight, and most of such pipe will run full card to a little above card, but owing to exigencies of manufacture, some lengths may run slightly below card, but never to the extent of more than 5 per cent.

You will note from the description of merchant pipe, that it runs from 5 to 10 per cent. below card, so that the stock used in full weight pipe is somewhat heavier than merchant pipe.

Extra Strong and Double Extra Strong Pipe are much heavier than either Merchant or Full Weight Pipe, but owing to their high cost, especially in the larger sizes, are not to be recommended for use except when the driving conditions are of the very worst.

In figuring sizes on Extra Strong and Double Extra Strong, it will be seen that while the walls are much thicker than Merchant Pipe, the external diameters are practically the same, the extra thickness being added on the inside, thus reducing the internal diameter.

As an example, 4 inch merchant pipe has an outside diameter of 4.5 inches, and an internal diameter of 4 inches, while 4 inch extra strong pipe has an external diameter the same as merchant pipe, but an internal diameter of 3.8 inches.

The couplings used on drive pipe are made extra long and heavy, and are provided with long sleeves to protect the threads from vibration and side strains.

Besides the coupling joints, drive pipe is also furnished with flush joints, and when extra or double extra strong pipe is used, flush joint pipe will stand moderately heavy driving.

The flush joint pipe is mostly used for driving through compact sand or gravel.

The advantage which it possesses over the coupling joint being that it presents a perfectly smooth surface on the outside, and can thus be forced through the clinging sands with the lightest possible blows.

# Size and Weight of Couplings.

| Standard Wrought Iron Couplings | | | | Drive Pipe with Patent Protecting Sleeve | | | | For Well Casing with Patent Protecting Sleeve | | | | | | | | Extra Heavy or Hydraulic Couplings, Recessed Ends | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size Inches | Outside Diam. | Weight Each | No. of Threads | Size Inches | Outside Diam. | Weight Each | No. of Threads | Size Inches | Outside Diam. | Weight Each | No. of Threads | Size Inches | Outside Diam. | Weight Each | No. of Threads | Size Inches | Outside Diam. | Weight Each | No. of Threads |
| 2 | 2 13/16 | 1¼ | 11½ | 4 | 5.1250 | 6.062 | 8 | 2 | 2.63 | 1.02 | 14 | 5 | 5.93 | 5.74 | 11½ | 1 | 1.63 | .56 | 11½ |
| 2½ | 3 9/32 | 1⅝ | 8 | 5 | 6.2500 | 8.812 | 8 | 2¼ | 2.88 | 1.24 | 14 | 5 3/16 | 6.18 | 6.04 | 14 | 1¼ | 2.07 | .90 | 11½ |
| 3 | 4 1/16 | 3 1/16 | 8 | 6 | 7.3750 | 13.800 | 8 | 2½ | 3.23 | 1.90 | 14 | 5 3/16 | 6.18 | 6.04 | 11½ | 1½ | 2.31 | 1.35 | 11½ |
| 3½ | 4½ | 3¼ | 8 | 7 | 8.3750 | 15.500 | 8 | 2¾ | 3.42 | 2.20 | 14 | 5⅝ | 6.62 | 6.45 | 14 | 2 | 2.81 | 1.80 | 11½ |
| 4 | 5 3/32 | 4¼ | 8 | 8 | 9.6250 | 23.300 | 8 | 3 | 3.77 | 2.70 | 14 | 5⅝ | 6.62 | 6.45 | 11½ | 2½ | 3.31 | 2.40 | 8 |
| 4½ | 5 17/32 | 4¾ | 8 | 9 | 10.4375 | 25.800 | 8 | 3¼ | 4.00 | 3.17 | 14 | 6¼ | 7.28 | 7.22 | 14 | 3 | 4.00 | 3.46 | 8 |
| 5 | 6¼ | 6¾ | 8 | 10 | 11.5000 | 39.500 | 8 | 3½ | 4.27 | 3.44 | 14 | 6¼ | 7.28 | 7.22 | 11½ | 3½ | 4.63 | 5.25 | 8 |
| 6 | 7 11/32 | 8½ | 8 | 11 | 12.9062 | 42.800 | 8 | 3¾ | 4.59 | 3.94 | 14 | 6⅝ | 7.69 | 8.35 | 14 | 4 | 5.13 | 6.80 | 8 |
| 7 | 8 11/32 | 11½ | 8 | 12 | 13.7500 | 46.100 | 8 | 4 | 4.81 | 4.15 | 14 | 6⅝ | 7.69 | 8.35 | 11½ | 4½ | | | 8 |
| 8 | 9 7/16 | 15¾ | 8 | 13 | 15.4375 | 49.000 | 8 | 4¼ | 5.06 | 4.20 | 14 | 6⅝ | 7.69 | 8.35 | 10 | 5 | | | 8 |
| 9 | 10 15/32 | 20¾ | 8 | 14 | 16.3125 | 55.000 | 8 | 4½ | 5.50 | 4.80 | 14 | 7¼ | 8.00 | 9.00 | 14 | 6 | | | 8 |
| 10 | 11½ | 26¾ | 8 | 15 | 17.5000 | 72.500 | 8 | 4¾ | 5.56 | 4.90 | 14 | 7⅝ | 8.70 | 10.00 | 11½ | 7 | | | 8 |
| 12 | 13 25/32 | 40½ | 8 | | | | | 5 | 5.93 | 5.74 | 14 | 8¼ | 9.37 | 11.52 | 11½ | 8 | | | 8 |

NOTE—The outside diameter of Couplings and weights in some cases vary slightly from the above list but to no great extent, and these figures can be depended upon as being as nearly correct as is possible to obtain them.

When it is necessary to use one line of pipe inside of another, the pipe to be inserted must have couplings with an outside diameter smaller than the inside diameter of the pipe in which it is to be used.

When it is known at the beginning that it will be necessary to case the well, drive pipe known as "plugged" should be used. "Plugged" pipe is pipe which has been reamed on inside to make pipe perfectly smooth.

## Galvanized Pipe.

It is the almost universal belief that galvanized pipe will last much longer than the ordinary black pipe, and also the water which stands in galvanized pipe is much purer than if the water stands in iron pipe. Neither of the above beliefs is true.

It might be that the galvanized pipe would last somewhat longer than the iron if it were possible to get it into the ground without breaking the thin layer of galvanizing, but under ordinary drilling conditions this is an impossibility, as the action of the drilling tools inside of the pipe soon wears deep scratches through the coating and into the iron. Also, when the pipe is driven through heavy layers of gravel, the sharp stones cut through the coating.

After the film of zinc has been broken through, it seems as though some sort of galvanic action starts up between the iron and zinc, and the rusting proceeds with even greater rapidity than if ordinary iron pipe were used.

In regard to the healthfulness of water standing in the two kinds of pipe, the verdict is much in favor of the iron pipe.

It is true that iron pipe, in rusting, forms an oxide, which, under some conditions is pumped out with the water, causing it to have a slightly reddish tinge, but this iron oxide is absolutely harmless, it is in fact rather healthful.

On the other hand, the oxides and carbonates which the zinc galvanizing forms, and it does form them, though slowly, are poisonous.

The writer knows of several wells, in which galvanized pipe was used, that have been abandoned or else have been re-cased with iron pipe, owing to the peculiar taste imparted to the water by the zinc.

An article bearing on the use of galvanized pipe, in the water mains of Rumford Falls, Maine, appeared in one of the recent Geological Survey Water Supply Papers, and from which, owing to its bearing on the above subject, we are taking the following extracts:

"An interesting case connected with this supply was reported by the manager of the water company. The inhabitants of the village objected to the water from time to time, for the reason that it was supposed to be contaminated. In 1905 a series of samples were collected and submitted for analysis to Prof. F. C. Robinson, of Bowdoin College. The results of these analyses are given in the table (Nos. 187 to 189), in which sample 1 was taken from the pumping station, sample 2 from the end of a long galvanized iron main, and sample 3 from Hotel Rumford. These analyses show that the total solids are rather low. In sample 2 there were 20 parts per million more than in 1 or 3. The chlorine, silica, calcium carbonate, sulphates of sodium and potassium, and sodium chloride are the same, or very nearly so, in all three analyses, but the carbonate of iron differs. The one surprising discrepancy in the analyses is that the amount of carbonate of zinc reported is 1.083 parts in sample 2, which was taken from the galvanized iron main, while samples 1 and 3 showed no zinc. It is also noticeable that the carbonate of iron is greatest in the sample taken from Hotel Rumford, while the iron in the water at the pumping station is small. This seems to indicate, as stated by Professor Robinson, that the water in traveling through a galvanized iron main dissolves a considerable quantity of zinc, owing to the carbon dioxide in the water. This gas is more often present in well water than in river or lake water, and it is a desirable constituent, but it seems to have a bad effect on the water by dissolving the zinc. The iron causes a deposit when the water stands. The zinc renders the water unfit for domestic use, and is probably the cause of some of the taste which is reported. For this reason Professor Robinson recommended that galvanized iron connections be taken out and connections of tin lined or brass pipe be substituted. The brass pipe is probably the best, but is more expensive. The bacteria in the water are all harmless. As seen by analyses, they were most numerous at the pumping station and decreased rapidly toward the points where the water was used. The results of these analyses seem to indicate strongly that the taste complained of was due to the use of galvanized iron connections. * * * * The pipes connecting with the mains in the streets are 16 inches in diameter, but in the distant parts of the town the mains are as small as 6 inches. There is one mile of 16 inch pipe, and in all there are about five miles of pipe. BLACK IRON PIPE IS USED AT PRESENT AND IT SEEMS TO GIVE SATISFACTION."

## Drilling Operations—(Continued).

After the first length of pipe has been driven, as described on pages 26 to 29, inclusive, remove the driving clamps from the stem and lower the tools into pipe. It will be noticed that the tools do not go to the bottom of pipe and also that when drilling, the tools strike the bottom as though drilling on some very hard substance.

The cause for this is that as the pipe is driven the sides of the hole are cut down by the drive shoe or coupling, thus forcing a plug or core up into the pipe.

This core will be found to drill much slower than the dirt, and thus it is best to drill the hole as large as possible so that the plug will not be driven into the pipe harder than necessary.

After this plug has been drilled out continue the hole by drilling and bailing until the top of rope socket comes about even with the bottom of pipe.

If the material being drilled is a firm clay or substance which stands up well, the hole can be drilled even further ahead of the pipe, but if there is any gravel in the material or for any other reason it shows signs of caving, do not allow the top of socket to pass out of pipe.

If it is possible to do so it is always best to keep the drill at least 3 to 5 feet ahead of the pipe, as the drill will cut out under the pipe, drilling a hole larger than the bit, thus making the driving of pipe much easier.

Drilling ahead also has the advantage of exploring the ground ahead of the pipe, and thus the presence of boulders or any other obstructions can be ascertained.

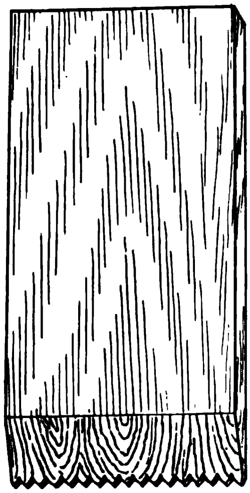
As the hole deepens connect on more pipe, driving it down as previously described. The length of pipe to be used depends upon the distance it is possible to drill ahead.

A close record of the lengths of pipe used should be kept so that the driller at all times knows the depth of lower end of pipe. In making measurements of pipe the lengths should be figured from the end of pipe to the middle of coupling.

Before screwing the different lengths of pipe together the threads should be carefully cleaned and liberally oiled, and if any threads are smashed they should be filed until smooth.

## Thread Chaser.

A simple little tool for cleaning dirt or grit from threads can be made as follows: Secure a piece of wood 2 inches wide, $\frac{5}{16}$ inch thick and of such length that it will go inside of pipe coupling. Bevel one end, making the bevel at an angle of about 30 degrees. Place the edge of beveled end of piece on the threads on end of pipe with the width of piece in line with length of pipe and holding it so that the length of piece is in line with diameter of pipe, tap it lightly with hammer. The threads will be driven into end of wood and will thus form a "chaser" corresponding to threads on pipe.

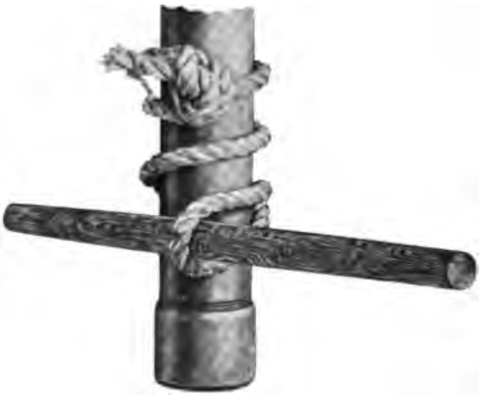


By following the threads with this tool all loose dirt and grit can be quickly removed. As this tool can be used for cleaning the threads on both the pipe and in the coupling, its length should be such that it can be used in coupling.

## Casing Pole and Rope.

As much time is consumed in screwing pipe together when pipe tongs are used, and as the handling of the heavy tongs is rather laborious work, drillers generally use what is known as a Casing Pole and Rope for screwing the joints together, only using the tongs for setting up the joints at the finish.

The construction and operation of this appliance is as follows: Take a piece of ¾ inch rope, 6 to 8 feet long and splice an eye in one end, making the eye about 5 or 6 inches long. Tie a knot on other end of rope, so tied that it comes within about 4 inches of end. Take the knot end of rope and starting it from left side of pipe, as you face pipe, make one turn around pipe. Now take the rope which comes along side of knot, and make a half turn around knot, and then wrap it from left to right until the rope is wrapped to the eye. This is the way the rope should be wrapped for screwing up the pipe. For unscrewing just reverse the operation.

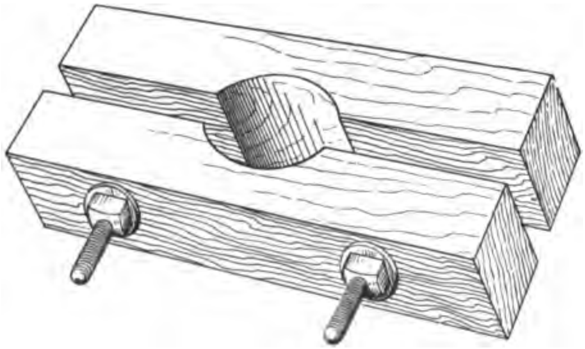


After the rope has been wrapped, place a 4 foot stick, 1½ to 2 inches in diameter through the loop, so placing the stick that the loop comes in the middle of the stick. This will leave handle 2 feet long projecting on either side of pipe. By the driller stationing himself on one side of pipe and the helper on the opposite side, the pipe can be screwed together in an almost continuous motion.

## Pipe Clamps.

Another device which often proves of assistance in handling pipe is a pair of pipe clamps.

It sometimes happens, when drilling a plug out of the pipe, that the drilling blows on the plug have a tendency to drive the pipe further into the hole, and as all joints of pipe should be connected at the surface where they can be thoroughly inspected, the clamps should be placed on the pipe to prevent it from driving into the hole. The clamps can also be used for pulling pipe with jacks. This point will be discussed later. Another use to which the clamp can be put is in starting a hole when the start must be made on solid rock. This point will be discussed further on.

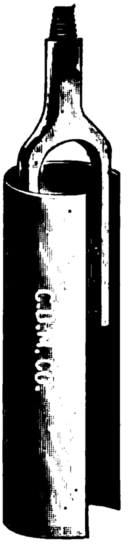


A pair of clamps can be made as follows: Secure two pieces of hard wood timber 5 x 5 inches or 5 x 6 inches, 3 feet long. Recess into the center of each piece a rounding cut about 1½ inches deep, the cut being laid off on a diameter equal to the diameter of the pipe. In both ends of each piece, and at a distance of about 8 inches from the center, bore an inch hole, so placing the holes in the two pieces that when the centers of pieces are placed together the holes come in line.

Use ¾ inch bolts to clamp the blocks together. Heavy bridge washers should be used on both ends of bolts, and the threads on bolts should be cut for a distance of three inches to allow for a varying range of pipe diameters.

## Drilling Through Clay.

As a rule clay will offer no serious obstacles. The main difficulty experienced is that it mixes with the water slowly, and thus if an attempt is made to force the drill into it the bit will become plastered with a "clay ball" which will prevent the tools from turning, also the bottom of hole will become filled with "clay balls" which will plug up the valve in bailer.



Excavator or Clay Socket.

In drilling clay, 25 to 30 feet of water should be kept in the hole, as an abundance of water will not only assist in mixing the clay but will also furnish water enough to fill the bailer, so that any clay balls which collect on the valve will will be forced out of bailer by the water when the bailer is dumped.

There are certain kinds of clays which, owing to their greasy nature, will mix so extremely slow that to make any appreciable progress it is necessary to handle them in a special manner.

The most common method employed is to dump sand or fine gravel into the hole. The sand under the action of the tools is forced into the clay, thus cutting its greasy texture and making it mix more readily. Usually one gallon of sand in a 5 inch hole will be found sufficient to mix with 1 foot of clay drilled.

Always dump in the sand before putting the tools in the hole as otherwise the tools are liable to be wedged.

Another means of drilling through clay is by the use of an excavator or clay socket. The socket is screwed onto bottom of stem in place of bit and is forced into the clay until it is full, by raising and dropping the tools, when it is withdrawn, the clay remaining in socket until surface is reached, when the socket is cleaned.

## Drilling Through Sand and Gravel.

As a rule sand and gravel present the most difficult drilling of any material encountered above bed rock.

Owing to the fact that it is impossible to drill but a short distance ahead of the pipe it is necessary, unless the pipe is driven ahead of the hole, to drill but a few inches and then drive the pipe.

In sand and gravel, hole can be made most rapidly by driving the pipe ahead and then drilling out the plug which has been forced up on the inside of pipe. When driving ahead, care must be taken, however, to see that the pipe is not driven onto a boulder, which will collapse the end of pipe or deflect it out of line. The blow used in driving should be just heavy enough to move the pipe. Do not allow the full weight of the tools to fall upon pipe, but adjust the stroke so that the blow delivered is just sufficient to keep the pipe moving. The presence of large boulders can then be detected, as the pipe, when the boulder is struck, will not drive and will appear to jump back after each blow.

When the pipe refuses to drive do not try to force it by using heavy blows, but remove the drive clamps, drill the plug out of pipe, and see what is causing the trouble. It may be that the plug has been driven so solidly that the pipe refuses to move under a safe driving blow, and if such is the case, the pipe can be made to drive by drilling out the plug. If a boulder is struck it must be handled as described further along.

Owing to the fact that sand does not mix with water, in the same sense that clay and water mix, quite a saving in time in drilling out a sand plug can be made if some clay is dumped into the hole before the tools are lowered. The clay serves the purpose of making a thick solution in bottom of hole, and thus holds the sand in suspension.

Clay can also be made use of when drilling through dry sand and gravel.

Sometimes a sand or gravel is encountered which contains no water, and is packed so firmly that a pipe cannot be forced ahead into it. Another trouble caused by this dry material is that the water which is poured into the hole is immediately drained off.

To make the hole hold water, dump in two or three gallons of stiff clay well chopped up, then pour in ten or fifteen gallons of water. The tools will force the clay into the spaces between the grains of sand and gravel, making the hole water tight. Not only will the clay seal the hole and make it hold water, but it will form a wall which will prevent the sides of the hole from caving, and will thus make it possible to drill ahead of the pipe.

One point to be carefully watched when driving pipe ahead of the hole and when the well is to be made in gravel, is that the pipe is not driven past a water bearing stratum, thus shutting off a good stream of water. If the well is to be made in rock, the above point need not receive any consideration but when it is desired to prospect each gravel stream, the bottom of the pipe must be opened up, from time to time, to allow a test to be made.

It sometimes happens that a fine sand is encountered which has behind it a strong water pressure, and which as soon as the plug is drilled out, forces itself up into the pipe. If the sand is very fine or is in the nature of a quicksand, it may rush into the pipe with such rapidity that, unless the driller is watching carefully, the tools may be covered and fastened in the hole.

A driller should always keep close watch of the drilling tools, but he should be especially careful about the time the bottom of a sand plug is being drilled through.

If the cable seems to become slack, or the tools seem to drag, the hoist should be immediately thrown in gear, and the tools lifted completely out of the hole.

As the sand is forced into the hole by a pressure which is behind it, the drilling out of a plug can be made much safer by filling the hole with water about the time the bottom of the plug is reached. The water in the pipe will balance the pressure behind the sand and will prevent it from coming in with a rush.

Instructions for making wells in sand and gravel will be given further along.

## Drilling Through Bouldery Ground.

Large boulders may be encountered in any part of the country, and in any kind of material above bed rock, but are most numerous in those regions covered by glacial drift.

If a boulder is struck fairly on top, it will be necessary to drill through it to determine its thickness, and then split it by the use of dynamite. This is done as follows :

After hole is drilled through boulder, and its thickness determined, fill up the hole with fine sand until bottom of hole comes about one foot below center of boulder. Place 2 to 20 pounds of 40 to 60 per cent. dynamite in hole. The amount of explosive to use depends upon size of boulder, but unless the boulder is more than three feet through, three to four pounds will usually be ample.

After the dynamite has been placed it should be covered with two or three feet of sand and the hole filled for at least twenty-five feet with water. the water serves as a tamping, thus confining the explosion and making it more powerful.

If the boulder has been encountered while drilling four or more feet ahead of the pipe, the charge can be fired without fear of injuring the end of pipe, but if pipe is seated on top of rock, it will be necessary to draw it back four or five feet.

The pipe can be drawn back by the use of Jack Screws or by means of Cyclone Pipe Pulling Device, description of which is given further along.

The dynamite should be fired by the use of a firing battery, as by this means it is possible to place the explosive at just the right point and then fire it when everything is ready.

Care must be taken in pulling back the pipe to see that the explosive is not disarranged, but the sand which was poured on top will hold it pretty firmly.

After the charge has been exploded lower the tools into the hole to determine the condition of same.

If rock has been split, drive pipe completely through it, using driving blow as light as possible. The reason for driving the pipe completely through is to shut off any pieces of rock which may have been torn from the boulder, and which might fall in on tools, wedging them in the hole.

Sometimes, though rarely, large boulders or pieces which have been torn from cliffs, and which are ten or more feet through, are encountered, and which may be mistaken by the driller for bed rock.

It is generally possible to tell whether or not the rock is a boulder by an examination and comparison of the materials which lie directly above and directly below the supposed bed rock.

Large boulders can be split the same as the smaller ones, but it may require the firing of several charges of explosive.

When boulders are struck in such a manner that the tools do not strike them fairly, but glance off at the side, they can be gotten rid of by shooting them out of the way. Four or five pounds of 40 per cent. dynamite placed in the hole opposite the boulder, and fired, will usually force the boulder far enough out of the way to allow the pipe to pass.

Do not attempt to drive the pipe past a slanting boulder as the pipe may be forced to one side thus making a slanting hole.

In those parts of the country covered by glacial drift, or in valleys between steep cliffs, boulders are often so numerous as to form "nests," in which the boulders are so interlocked as to make it impossible to drive pipe through them. These "nests" can be spread apart by firing repeated charges of explosive.

**Caution**—If the reader is unfamiliar with the handling of explosives, we would suggest that he secure the services of someone to instruct him or else purchase some good book on the subject.

If a few fundamental principles of the action of explosives are understood, and the explosives handled in a careful and intelligent manner, there need be no excuse for accidents, but as it is true, as some mining engineer recently said, "The business of explosives is to explode," we would urge that no chances be taken.

## Seating Drive Pipe in the Rock.

When seating drive pipe in the rock care should be taken to see that an absolutely tight joint is made. This is an extremely important point to watch if flowing water is being drilled for, as a loose connection between the bottom of pipe and the rock may allow the water to flow off through some subterranean channel between the surface of the ground and the bottom of pipe, and thus the water will never reach the surface, or if it does reach the surface, the stream which flows will be much smaller than otherwise would be obtained.

Even if flowing water is not expected, it is necessary, to make the best well, to make an absolutely tight joint. If a hundred feet or more of pipe is driven, the water will usually stand several feet up in the pipe, and many times comes within a few feet of the surface. It can readily be seen that if a tight union is not made, the water will have a tendency to flow off between the bottom of pipe and the rock, thus reducing the strength of the stream and placing of the pump cylinder much lower in the well than otherwise would be necessary, thus making the pump work much harder. Not only does a leaky union make it necessary to place the cylinder lower, but it causes a large loss of water, and this is a thing that every driller should guard against, and must guard against if the well drilled is expected to be pumped to its fullest capacity.

Many concerns using water from several wells now pump them with compressed air, and it has been fully demonstrated that a leak between the pipe and the rock, which allows the water to partially drain off, reduces the efficiency to a marked degree.

It may be thought that where the bed rock lies directly below a thick bed of clay there is no chance for the water to escape, but you must remember that the coupling, or drive shoe, on the end of pipe, cuts a hole larger than the pipe, and as the water is often under many pounds pressure, it will force itself up along side of pipe and flow off in the first porous stratum encountered.

To properly set the pipe it should not come closer than four feet of the rock, until the rock has been penetrated to a depth of one foot. By doing this the bit will cut under the pipe, and the hole which is drilled into the rock will be larger at the top than the size of the bit, and gradually taper down until it is practically the same size as bit. Thus a funnel-shaped hole will be started in the rock, and the pipe when driven will wedge tightly in the hole.

If gravel lies immediately above the bed rock it will be impossible to drill so far ahead of the pipe, and thus the pipe will have to be driven to rock before a seat is provided for it. In this case, after having drilled into rock for about six inches, drive the pipe, using light blows. The idea is to force the drive shoe to chip off the sides of hole and bury itself in the rock.

Sometimes the top of bed rock is soft and after the hole has been drilled it is possible to drive the pipe into it for some distance. In driving pipe into rock use light blows, as the drive shoe has to force itself into the hole by chipping off the rock, and if heavy blows are delivered the threads on pipe may be stripped and the pipe telescoped.

In some parts of the country the bed rock is found to lie at an angle, and unless the driller is very careful the hole in rock may be started on a slant, thus necessitating reaming out and straightening up the hole. When slanting bed rock is found the drive pipe should be driven until the pipe rests on high side of rock, and then the slack taken up in cable until the tools just touch the bottom. Do not try to hasten the work by allowing the tools to strike full weight as they will glance off and a crooked hole will almost invariably result.

If you find that the hole is going crooked in spite of all you can do, it will have to be reamed out, and this process is described further along.

A slanting or crooked hole can be determined by the action of the tools.

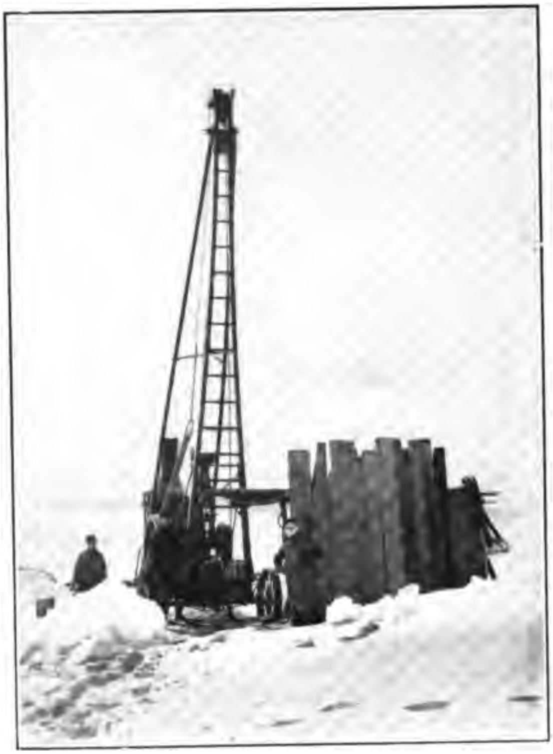
In a crooked hole the top of the tools seem to drag and the tools do not turn free but seem to bind when turned in different directions. This is due to the fact that the cutting edge of the bit is longer than it is wide, and when the long way of the bit is turned against the crook in hole the tools seem to stick and bind. By examining the drilling tools it is also possible to determine whether or not the hole is straight, as tools when used in a crooked hole are severely scratched and worn. These scratches will be found on the collar of bit and along the collars of Rope Socket and top of Stem.

After the pipe has been seated and the rock penetrated for about two feet the union between pipe and rock should be tested by filling the hole with water. If the water does not maintain its level it is certain that the joint is leaking, the amount of leak being determined by the rapidity with which the water recedes in the pipe.

If you are unable to stop the leak by further driving of the pipe, it will be necessary to cement the bottom of hole.

To do this, bail all the water from the hole and fill it for about 4 feet above the bottom of the pipe with 3 parts cement and 2 parts very fine sand. If you are unable to secure very fine sand use simply the cement and water, as the sand, unless very fine, will fill up the small spaces and not allow the cement solution to get in around the pipe. After the solution has been placed in the hole lower the drilling tools and by placing the cable on Spudder, churn the tools up and down for about 10 minutes. This will force the cement into the spaces around the pipe. Next remove the tools and bail out the solution until it comes but 3 or 4 inches above the bottom of pipe.

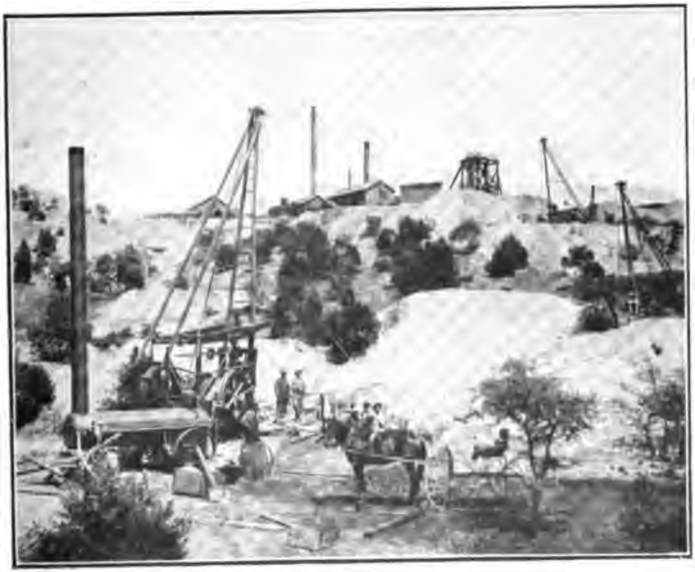
It is not absolutely necessary to remove the surplus solution, but if it is removed it makes that much less plug to drill out. If the hole is dry allow the solution 24 hours in which to set, but if the hole makes water in any amounts at all it will be necessary to give it at least 60 hours.



**A No. 4 Cyclone**

in winter quarters
on a deep hole.

Hole being drilled
with wire line.



**Copper Prospecting**
at
Santa Rita,
New Mexico,
with
Cyclone
Cable Drills.

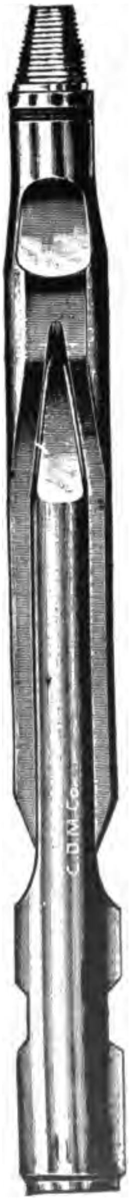
When drilling wells in valleys or along river or creek bottoms, it is sometimes found that the bed rock is covered with gravel in which there is a very large amount of water.

When the above condition is met it is often impossible to cement the hole, owing to the fact that the amount of water is so great that the cement solution is washed away as fast as it is put in the hole. To make a tight union under this condition, it is necessary to drive to bed rock a pipe of internal diameter large enough to admit a pipe of the size that it is desired to drill the well. Thus, if the well is to be 4 inches in diameter, it will be necessary to drive a 6 inch pipe to bed rock. After the 6 inch pipe has been driven solidly to the rock, drill into the rock for a distance of 2 or 3 feet, with the 6 inch bit, and then put on a 4 inch bit, and continue the hole for another 2 or 3 feet.

In starting a 4 inch bit, in a 6 inch hole, care must be taken to see that the hole does not drift off to one side, as a 4 inch bit has quite an amount of play in a 6 inch hole. To prevent drifting, the cable should be kept tight, and the tools just allowed to strike the bottom. If you have a 5 inch bit, is is safer to reduce from the 6 inch to the 5 inch and then from the 5 inch to the 4 inch.

After the hole has been reduced to 4 inches, place the 4 inch pipe inside the 6 inch pipe, and continue the 4 inch pipe from the top to the bottom of the hole. After 4 inch pipe has been seated, tap it lightly with the tools to set it firmly.

Test the 4 inch pipe to see whether or not it leaks at bottom, and if it holds water, the 6 inch pipe can be pulled leaving the 4 inch pipe in the ground.



Jars.

## Drilling Jars.

As soon as the bed rock is reached, and the pipe properly seated, the jars should be placed on the tools.

For ordinary drill work, the jars are placed between the rope socket and top of stem. To do this, allow the tools to hang in the hole and break the joint between rope socket and stem, and then, placing the left hand tool wrench on square of stem allow the weight of tools to rest on wrench. The left hand wrench should be used as it will then come right for setting up joint after jars have been screwed onto stem.

Allow the weight of tools to rest on wrench and then unscrew the rope socket. Next screw socket onto jars and hoist the socket and jars until they hang directly above the stem. Now connect jars to stem and set up the joint with wrenches. After this joint has been set up lower the tools and set up joint between socket and top of jars. Before taking off the wrench to lower the tools, to set up the top joint, this joint should be examined to see that it has not been unscrewed while setting up the joint between bottom of jars and top of stem.

Tool Wrenches.

Jars are constructed with a link connection, the link as a rule having a stroke of from 5 to 8 inches. Some jars are made with a stroke of from 20 to 36 inches, but these are made especially for fishing jobs, and are not to be recommended for regular drill work.

The use of jars adds nothing to the direct drilling efficiency of a set of tools, the only time they are called into use being when the tools become fast in the hole.

In drilling, the cable is kept perfectly taut and the blow delivered by the tools on the bottom of the hole, comes from the stretch of the cable. As long as the cable is kept at the right tension, the jars do not open and it should be the aim of the driller to so regulate the stroke and tension on the cable, that the bit strikes on the bottom of hole without movement on part of the jars.

In case the tools become fast in the hole, let 6 to 10 inches of slack in the cable, and if the machine is operated by steam power, run the engine on the forward direction and then on the reverse. If the machine is operated by gasoline power, let in slack enough so that the spudder crank will pass lower center. You will note, that when slack is let in cable, and the spudder operated that a heavy blow is delivered. It is for the delivery of this blow that the jars are used.

It is a well known fact that a blow is much more effective than a straight pull, and thus while the tools often become so firmly fastened in the hole that it is impossible to loosen them by a straight pull, they can be easily loosened by a few blows of the jars. After the tools have become loosened take up slack in cable, and continue drilling as before.

The jars should be carefully watched to see that they do not crack and each time the tools are removed from the hole, the jars should be tested by striking each rein with a hammer. A cracked rein can be detected by the flat sound it gives out when struck.

It will be noted that after jars have been used some time, a burr forms where the two links come together. This burr should be kept trimmed down, so that jars work easily.

The reason jars are not used when drilling above bed rock is that there is little liability of the tools becoming fastened when drilling in clay, sand, gravel, etc., and as the jars add about 5 feet to the length of the tools, it makes the handling of pipe more troublesome.

## Drilling in Rock.

The first thing to learn when drilling in rock, is to get the proper stroke to the tools. In the softer materials above bed rock, a close adjustment of the stroke is not of such importance, but where it is desired to cut rock at the best possible rate, it is absolutely necessary that the stroke be just right. It will be noted that the tools have a tendency to bounce when the rock is struck, this tendency being greatest in the hard rock, and the engine should be run at such a speed and the cable kept at such a tension that the tools are caught on this upward bound.

If the tools are run at such a slow rate, or the cable is so slack, that the tools settle back after each blow, it not only requires more power, but the cuttings will have time to settle in the bottom of the hole and thus the tools instead of striking firmly on the bottom of hole, will have their force partly cushioned by the cuttings. By keeping the tools at the proper speed, the chips which are cut from the rock, are kept afloat and thus the cutting edge of bit strikes the rock with full force.

Owing to the fact that there is quite an amount of stretch in a manila cable, it will be found, if the tools are stopped after having been run at proper speed and with proper tension in cable, that the tools do not touch bottom of hole. This shows that the blow which is struck at each stroke, comes from the weight of tools stretching the rope, this being called by drillers, "drilling on the spring of the cable," and is the only correct way to drill in rock.

The amount of water in the hole also has an important bearing on the rate of drilling speed. If there is a large amount of water covering the tools, it has a tendency to buoy them up, and thus the blow is not only deadened but the tools can not be run as many strokes per minute.

Another trouble caused by a large amount of water is, that the sludge is made so thin that the cuttings settle very quickly to the bottom, and thus the tools do not fall with full force on bottom of hole.

If possible just enough water should be used to come even with the top of stem when tools are in the hole. This will allow sufficient water to mix with 3 to 4 feet of cuttings and will keep the sludge thick enough to lift the cuttings off the bottom.

In bailing out after a run, 1 to 1½ feet of the sludge should be left in hole, and then enough water poured in to bring the water to top of stem.

As the tools, when lowered into the hole, displace an amount of water equal to their volume, it will be necessary to experiment to determine the amount of water necessary to add in order to bring the water to proper level. Thus if a certain size of tools is used in a 5 inch hole, it will take a certain amount of water to bring the water to top of stem, while in a 6 inch hole, the amount will be greater for the same size of tools.

Some drillers, in order to deaden the sound of the jars, completely cover the tools with water, but it has been the writer's experience that every extra foot of water added to the hole decreases the drilling rate, and as a driller is usually paid for the number of feet drilled, it will be found to his interest to use less water and make more noise,—and money.

When drilling in some holes it will be found that the rock "bleeds" a small amount of water, and if this amount is not great the driller can take advantage of it by not pouring any water in the hole, and letting the hole furnish the water needed. If the "bleed" is to be relied upon for water, the sludge should be bailed out until only about 1 foot remains in the hole, this furnishing enough water for starting the tools, and as the hole deepens, the small amount of water coming into the hole will take care of the extra cuttings.

The sludge in hole should be kept about the thickness of a medium stiff batter, and it is for this reason that a foot or more of the old sludge should be left in the hole after bailing out, so that the sludge will be thick to start with.

When a hole is several hundred feet deep and the amount of water made by the hole is so great that it covers the tools by 200 feet or more, a sinker bar is sometimes used above the jars. The sinker bar is nothing more than a short stem, and is placed between the rope socket and jars to add more weight on bottom of rope, thus sinking it more swiftly through the water. As the bar is placed on the top of jars, it adds no extra force to the drilling blow, only in as much as it pulls the cable down more rapidly, thus giving a quicker drop to the tools.

The different kinds of rock encountered in drill work can be covered by the following classification :

Shales. Slates. Sandstones. Limestones. Granites.

While the writer does not mean to say that the five kinds of rock formations named above will be the only kinds met, he does mean to say that all the drilling characteristics of any rock formation will be found very similar to one of the above classes. If, therefore, a driller is acquainted with the peculiarities of the above classes, and understands handling the same, he may feel confident that he is prepared to meet all kinds of rock drilling. It would not be possible, in a book of this size, to describe each individual class of rock formation, and as the above named formations are generally known, they will be used as a general classification to cover all rock drilling.

**Shales**—While a shale can hardly be classified as a rock, still, owing to the fact that the walls of a hole through shale are usually sufficiently firm to stand without casing, it may be classified, at least by drillers, as a rock, or rock formation. As shale is formed from mud, it is found in all degrees of hardness from that of mud itself, up into the slates into which it passes.

Shale, as a rule furnishes the easiest drilling which can be found. Being soft and not very firmly consolidated it chips up into large cuttings of light weight which are easily held in suspension, thus permitting of very rapid drilling.

Owing to the fact that shale cuttings soon form a very thick sludge at bottom of hole, and also owing to the fact that shale cuts rapidly, it is necessary to pay particular attention to see that the tools are turning, or otherwise, a flat hole may be drilled.

In passing from a soft shale into a hard stratum, it is necessary to exercise care to see that the tools do not drift off to one side, as a soft shale does not offer much support to the tools. Also it is necessary to watch to see that no hard nodles or kernels, which might extend into side of hole, throw the tools to one side thus causing a drifting hole. A good stiff tension should be kept on the cable at all times, and at the first sign or indication that the hole is drifting it should be made straight. Not only should the cable be kept tight to prevent the tools from drifting, but as shale formations usually contain many thin, soft, clayey bands, it is essential that the cable tension be kept pretty stiff, in order to prevent the tools from sticking when breaking through.

In some parts of the country, where the geological formations are comparatively new, the shales do not seem to have had time to become very solid, and thus caving trouble is experienced. Where there are no hard bands in this soft shale, it can be drilled the same as the soil above, by protecting the lower end of drive pipe with drive shoe, and driving it through the shale. If hard bands are present, it will be necessary to use an under reaming tool or else start hole large enough so that it can be recased.

**Slates**—Slates, so the geologists tell us, are formed from the shales, by pressure and heat. They are usually much harder than shales, and will always be found with a well defined cleavage. As a rule the cleavage plates are not of great thickness and are very brittle, fracturing at a blow.

Owing to the brittleness of slate, and to the thinness of the strata, there is a constant tendency for the tools to stick, as the edge of bit breaks through the thin layers. This is one of the most pronounced drilling characteristics of slate, and this sticking of tools can be avoided only by keeping a stiff tension on cable, and having the bit properly dressed. We have already discussed the importance of keeping the proper tension on the cable, and the correct dressing of tools will be taken up in a later chapter.

Slates will be found with their strata lying at all angles from, the horizontal to the vertical. When the drilling is through vertical, or highly slanting strata, the tools have a tendency to follow the inclination of the strata, and, unless attention be paid, a slanting or crooked hole will result.

If the strata are of equal hardness and lie snug against each other they are not nearly so apt to cause trouble as when they are of unequal hardness or have open spaces between them. The reason for this is that the bit will cut the soft strata more easily than the hard ones, and thus the tools will be deflected towards the softer side.

Slates often contain masses of amorphous iron pyrites ranging in size from pieces the size of a walnut up to pieces the size of a man's head. These masses which are called Sulphur Balls, by the drillers, are extremely hard, and if they occur in the side of the hole and are firmly imbedded in the slate, may cause the tools to be deflected from a straight line. Even though the sulphur balls break loose from the slate and fall to the bottom of the hole, they may still cause trouble as they are very hard to crush, and if they happen to wedge on one side of the hole, are sure to force the tools to one side.

Sulphur Balls are also hard on the bit. Being very much harder than the bit, they will soon break down the corners and batter the cutting edge. A bit which has been run for some time on a sulphur ball will be grooved and cut from the cutting edge upward very much as though it had been working on tempered steel. So pronounced is this similarity that drillers unfamiliar with the hardness of Iron Pyrites and drilling on it for the first time, often believe that someone has been placing tempered steel in the hole.

The hardness of slate varies from slates no harder than soft shales to slate possessing a hardness equal almost to that of granite. Often slate will be found with quartz bands lying between the various strata. Slates are also sometimes found with various minerals lying between the different layers, the minerals having been deposited by infiltrating waters. As a rule, state will be found to be an easy drilling rock, as it usually cuts rapidly, and offers no obstacles which can not be easily overcome, if attention and care are given to the work. Of course when slate contains a large amount of mineral matter, or is full of quartz, the drilling becomes slower and an extra amount of attention must be given to see that the hole is kept in good shape.

Often times slate is mistaken by inexperienced drillers for coal, and many coal discovery excitements have originated from enthusiastic drillers who have penetrated a few feet of slate. Sometimes the slate is of a bituminous nature and then there is a certain similarity between the two so that there is some excuse for an inexperienced man being mistaken.

As this is a book on well drilling and not mineral prospecting, we will not go further into this subject, but we would suggest that before starting an excitement by declaring you have struck coal, you have the cuttings examined and reported on by a person competent to decide.

**Sandstone**—Sandstone is formed from sand formations by the grains becoming cemented together by infiltrating waters, which carry the cementing material in solution. The cementing material is usually either iron oxide, calcium carbonate or silica.

The amount and kind of material deposited determines the hardness of the rock, and thus sandstone is found in all degrees of hardness from the rock which can be crushed between the fingers, to the quartzites, which almost equal pure quartz in hardness. While geologists do not list quartzite as a sandstone, yet, as it is made up from sandstone, we will, in the broad classification which we have adopted, classify it as such.

The most pronounced drilling characteristic of sandstone is the rapidity with which it wears the bit out of gauge. Even the softest sandstone will wear a bit rapidly. This is due to two causes. The first cause, is the rubbing of the bit against the side of the hole, an action very similar to whetting a tool on a whetstone, and one for which there is no remedy except to temper the bit very hard.

The second cause is the presence of the sharp grains of sand in the bottom of the hole. In a sandstone, as a rule, there will be found no material which will serve to make a thick sludge, in the sense of shale sludge, and thus the grains of sand instead of being held in suspension in the water, settle to the bottom of the hole, making it necessary for the cutting edge of the bit to be driven through these sharp grains at each stroke. It will be noticed that a bit which has been properly tempered, when run in medium hard rock will be sharper on the cutting edge, after running, than before put in the hole, and this is due to the action of the loose sand.

There is but one way to prevent the wearing action of this loose sand and that is to hold the sand in suspension. This can be done, to a certain extent, by dumping clay into the hole as described on page 44.

Owing to the trouble experienced in keeping the sand off the bottom, it is best to bail out after each three or four feet drilled, as otherwise the amount of loose sand becomes excessive. This is especially true if the rock is soft or of medium hardness, as the rock drills so rapidly that the sand grains are simply broken loose from the cementing material without being crushed. In the hard sand rocks or quartzites the grains are so firmly cemented that they are pulverized as they are broken loose and thus, being ground up fine, are not so troublesome to hold in suspension in the water

If much sand rock drilling is to be done, it is best to use the vacuum type of sand pump, described on page 17, as with this pump the hole can be quickly cleaned after each run.

The reason for using the vacuum pump is that the sand cuttings settle very rapidly and pack very firmly and are not easily removed by the ordinary bailers.

If an ordinary bailer of the flat valve or dart valve type be used, it should be pumped up and down on the bottom of the hole, so as to loosen up the sand and cause it to enter the bailer. There is quite a knack about "pumping" a bailer, as it must be so handled that the valve acts as does the valve in a pump, thus drawing the cuttings into the bailer. If the hole is not over 300 feet deep, and the bailer is not over 3½ inches in diameter, it can be pumped by hand. By grasping the bailer line, lift the bailer from 8 inches to 1 foot off the bottom of hole, then slack down on line until bailer valve touches bottom and opens, and then with a quick upward jerk lift bailer 8 inches to 1 foot again. Repeat these operations eight or ten times, when the valve will have drawn sand enough into bailer to clog valve. You will note that at each upward jerk the valve closes with a bang, and you will soon learn to tell from the sound of the valve how the bailer is working.

The above instructions are for operating a bailer with a dart valve. When the bailer is fitted with flat valve, the operation is the same, except that on the downward movement, the bailer must be allowed to strike bottom of hole, before the upward jerk is given.

If the bailer is too large to operate by hand it can be operated by the engine. If the engine is used care must be exercised to see that too strong a jerk is not given, as otherwise the line may be parted.

Another type of rock which geologists call conglomerate, but which, owing to the fact that the particles are cemented together, we will list under the head of sandstone, is composed of large rocks, small pebbles, and sand cemented together.

Where the cementing material is of a silicious nature, and the rocks and pebbles composing the mass are formed from granite or gneiss, or as they are usually called "Nigger heads," a conglomerate makes extremely slow drilling, but if the cementing material has been thoroughly distributed and has filled all spaces, while the drilling rate may be very slow and may require several bit dressings to each foot drilled, nevertheless there is no more trouble to be expected than in other hard rock.

If the cementing material does not bind the rocks and pebbles together firmly enough so that they can be crushed by the bit without being broken loose from the matrix in which they are held, then more care must be exercised to see that the tools are not deflected out of line by the loose rocks which are drawn into the hole and off of which the tools may glance. The usual, and always important stiff tension should be kept on the cable and the bit should be dressed very flat. As the bit dressing will be taken up separately we will leave this discussion for the bit dressing chapter.

**Limestone**—Owing to the fact that all limestones were originally formed under water, they will almost invariably be found in a stratified condition.

In some parts of the country the limestones, due to changes which occurred after they had been laid down, have become cemented together so that they present the appearance of a solid unbroken mass.

Limestones will be found with the strata lying from horizontal to vertical, and thus what has been said about drilling through slanting strata under slates, applies also to limestones, it only being necessary to bear in mind the difference in structure between the two classes of rock formations.

Owing to the fact that limestone is readily soluble in water which carries carbonic acid gas in solution, caves and water channels of considerable extent will sometimes be encountered in that portion of the formation which lies above permanent water level.

The enormous caves of Kentucky and Indiana are in limestone formations and are the result of the solvent action of water.

Limestones will be found in all degrees of hardness from the porous, spongy, dolomitic variety which can be crushed in the hand, to the close grained silicous variety, which is almost as hard as flint.

In fact, the waters which circulate through the cracks and pores in limestone often deposit such large amounts of silica that the limestone is entirely replaced by the silicious matter, and where this occurs, the deposited mass, which is usually called chert, makes extremely slow drilling, being as hard and tough as the hardest granite.

While limestone may be extremely difficult to drill, owing to the hardness it may attain, yet as the grains of which it is composed are not abrasive like sand grains, it does not rapidly wear the bit out of gauge and thus the only problem in the bit dressing is to so shape and temper the bit that it will neither dull nor crumble.

As the different strata were originally laid down under widely varying conditions, it is natural that we should find the several strata which go to make up any limestone member, vary greatly in thickness, hardness, etc. Thus strata 2 or 3 inches in thickness may alternate with strata several feet in thickness.

In breaking through from one stratum to another, the drill bit will sometimes stick, owing to the fact that a soft gouge, from the fraction of an inch to several inches in thickness, may separate the strata and thus allow the edge of bit to slightly bury itself.

If drilling is being done through strata which vary in hardness, that is when the drilling is first in a hard stratum and then in a soft one, it is necessary to exercise care to see that in breaking through from the hard to the soft stratum, the hole is kept round, as it sometimes happens that the drill bit will drive down into a very soft material and drill ahead without turning. This will not only result in a flat hole but it may cause a crooked hole.

To be sure the tools are turning, put a stiff tension on cable and twist it several times in one direction and test the action of tools as described on page 25.

The instructions given above apply to drilling where the strata lies horizontal or nearly so.

For drilling where the strata lie at a high angle the same precautions advocated under slate drilling should be observed.

When open spaces of considerable extent are encountered in the path of the drill, the hole can be continued on down by letting sufficient slack in cable to allow tools to just touch the lower bottom and then run them at slow speed until a depth greater than the length of the stroke has been reached, when the tools can be again run at full speed.

If the height of the open space is greater than the full length of the tools, then more care must be exercised to see that the tools make a start in a line with the hole above.

Owing to the fact that the tools, when working in such a large open space have no confining wall to hold them in line, they will oscillate violently, and it will be necessary to stop the tools every few minutes to allow them to straighten up. It will greatly assist matters to shorten the stroke of drill, as much as possible, and run the machine at this stroke until the tools have penetrated to a depth of about three feet. Do not speed up the machine until the hole has reached a depth of at least one-half the length of the tools, as otherwise the oscillation of top of tools may become so violent as to snap the pin on bit.

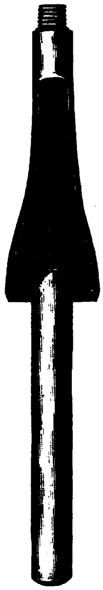
It sometimes happens, owing to a slanting bottom, that it is impossible to make the drill bit take hold. When this occurs, the bottom can sometimes be straightened up by firing heavy charges of dynamite against it. If the rock is of medium or above medium hardness, 8 to 10 pounds of 60 to 80 per cent. dynamite should be used. A high per cent dynamite is recommended for this work, owing to the fact that no tamping can be placed above the dynamite to confine its force. The dynamite should be lowered until it just rests against the bottom, and then fired. If the first charge fired does not seem to do any good, try firing one or two more charges, and then if the drill does not take hold, it will be necessary to case the hole.

In putting in the casing, it should be set clear to bottom of hole, so that it will serve to guide the tools and prevent the bit from glancing.

After the pipe has been set, the tools should be started by using very light blows, so that the glancing effect of the tools on the slanting surface is reduced to the minimum. In fact, the stroke of the tools should be so adjusted that the tools just touch, until a square shoulder has been cut down.

It will of course be readily apparent that after the hole has been cased, it will be necessary to use smaller tools for continuing the hole, unless, after the hole has been drilled down 6 or 8 feet, the casing be removed and a double winged reamer with guide stem be used for enlarging the hole to the size of hole originally drilled.

The action of the side wing reamer will be readily understood by referring to the cut. The guide stem extending below the wings guides the reamer in the hole, and the two wings, cut down the sides of the hole to the required size. After the hole has been reamed down 3 or 4 feet, or at least deep enough to allow a stroke to the tools without the tools coming out of the hole, the regular bit can be put on and the hole continued on down.



Double Winged Reamer with stem.

**Granite**—Nearly all granite is of igneous origin, and unless disintegrated or decomposed is usually of great hardness. Not only is the rock extremely hard but it is also very tough and thus offers great resistance to any kind of cutting tool.

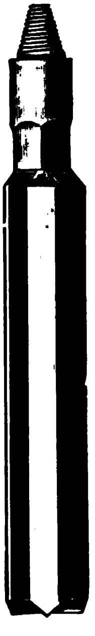
As about all granite was originally in a molten mass, it is never found in a stratified condition in the same sense that limestone and shale are stratified. Sometimes, due to strains which have occurred after the mass has been deposited, granite is given a stratified structure, but when this occurs there is generally a rearrangement of the different constituents of the granite and the resulting formations are called gneiss and schist.

The gneiss is very similar to granite, the stratification planes being shown only by the arrangement of the mineral particles in bands and not by any pronounced cleavage planes. On the other hand the schist has well defined planes of cleavage and thus its drilling characteristics are very similar to slate, it, however, unless weathered, being usually much harder.

As we have stated, granite is very hard and very tough and this is probably its most distinctive characteristic. The feature, however, which generally causes the most trouble to a driller is the presence of what geologists term joints or joint planes, but which are usually called cracks by drillers. These cracks occur all through the granite and intersect each other at all possible angles, and thus blocks of granite from the smallest fragment up to pieces of enormous size are bounded by joints or cracks, which may range in width from a hair's breadth on up. As a usual thing the cracks are not of great width, most of them being below 2 or 3 inches.

Granite, owing to its extreme hardness and toughness, would make extremely slow drilling even though the formations were solid, but where joints or cracks standing at a high angle occur in the path of the drill, the drilling problem resolves itself not only into a question of slow drilling, but into one of difficult drilling. The horizontal or nearly horizontal cracks hardly ever offer trouble, but extreme care must be exercised in drilling across highly slanting cracks, not only to prevent the hole from going crooked but also to prevent the joints on the tools from being broken.

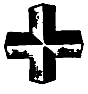
For drilling in granite the joints on the tools should be the very largest it is possible to use,in a hole of the size being drilled. It is very rarely that a hole can be put down in granite without striking at least one bad crevice, and if the tools are provided with small joints the weight of the stem forcing the bit against a slanting wall is very liable to cause trouble.



If the cracks are not over an inch in width and if both walls of the crack are of equal hardness and if the proper kind of bit is used, then there should not be much trouble experienced, if a stiff tension is kept on the cable and the bit has been properly dressed.

A thin bit should never be used for granite drilling. The bit employed should be as thick as it is possible to use in the hole and should maintain this thickness from the top of wearing surface to within a few inches of collar. This style of bit is called a Mother Hubbard Bit, and owing to the fact that it completely fills the hole, it will prevent the tools from drifting, thus keeping the hole straight It will also prevent the tools from sticking as the bit is about as thick as it is broad and thus it cannot swing sideways and fasten itself in the crack.

Another style of bit which has proven very satisfactory for hard drilling and creviced rock is the Star Bit. The four wings of this bit tend to keep the tools in line with the hole and thus prevent drifting. The disadvantages of the Star Bit are that it is harder to dress than an ordinary bit and the corners being thinner it requires more frequent dressing when used in a hard, sharp rock like granite.



Star Bit.

When slanting strata occur, of such nature that they throw the tools out of line, and the hole goes crooked, it is necessary to resort to special means in order to straighten up the hole. Various devices are used for this purpose, such as reamers, hole straighteners, and similar appliances which will be described further along, but for a stubbornly crooked hole in hard granite it has been the writer's experience that only two remedies are at hand.

The first which should be tried is to fill the hole up past the crack with broken grate bars, pieces of files, pieces of plow shares, in fact any kind of steel or iron scrap which can be found, so long as the pieces are of a size not larger than 2 in. x 3 in. x 1½ in. thick.

The cast iron pieces can be larger, but it is best not to get the pieces of steel of greater size.

The bit should be dressed so that it is very blunt, but having a full wearing surface. The iron and steel will not only keep the bit working at one point a long time, thus giving it a chance to take hold of the rock, but the action of the bit will force the steel and iron out against the sides of the hole with such force that it will chip away the rock thus assisting the bit in "eating out" the crook.

If, after once drilling out the iron, it is found that the hole is still crooked try the same thing over two or three times more as a hard rock requires a great deal of pounding to remove a crook. However, if you find after three or four trials that you are doing no good, then it will be necessary to shoot the hole. In shooting a hard granite a high per cent dynamite should be used. If the crook is a bad one, it will be necessary to use from 25 to 50 pounds of dynamite to cause any effect, but it is always best to use the least amount possible to get results, as an excess of dynamite shatters the rock very badly, and while this will in all probabilities not affect the future usefulness of the well, the presence of the shattered fragments in the hole will be a constant menace to the tools, should the hole be continued on down.

You will note that the writer has recommended a high per cent dynamite and if this kind of dynamite is used it must be handled with extra care as it is much more easily exploded than the lower per cent explosive.

It will be noted that in drilling in some granite the bit will be worn as rapidly as though sandstone were being drilled. This is caused by drilling a granite in which the quartz is of a crystalline nature. As a rule the quartz or silica is more amorphous, thus being tougher and while the bit does not show the excessive wear in this class of granite which it shows in the highly crystalline species, still the drilling speed is slow in the close grained, tough variety, and instead of the bit wearing excessively it simply batters out of shape, due to the extreme hardness of the rock.

# PART II.

## Bit Dressing.

THERE is a saying in the oil fields that "The driller makes the well, but the tool dresser makes the hole," the meaning of which is that the speed made in drilling depends entirely upon the correct dressing and tempering of the bits. While this statement is, of course, not wholly true there is yet enough of truth in it to make it well worth remembering.

A dull bit or one improperly dressed or tempered is a mighty poor investment for a drill contractor. If the bit is dull the drilling rate is greatly reduced and if the bit is improperly dressed or tempered it will not run but a short time before it will need re-dressing. As the only time your drill is making you money is when it is hitting on the bottom of the hole, it is necessary, if you want to make the most possible feet in the shortest space of time, to so regulate the work that the tools will be above ground as few times as possible.

A great many men when starting in the drilling business, seem to think that if they understand the operation of the machine, it is not necessary to pay much attention to the rest of the work. This is a very much mistaken idea. All parts of the drilling outfit demand attention, but by far the most important single thing of the whole equipment is the drill bit. This is the business end of the outfit. To the bit belongs the duty of gnawing a hole through the gravels and hard pans, forcing its way through crevices and slanting strata, and finally breaking down the rocky barriers which confine the underground streams. Upon the bit falls the brunt of the battle, and the service which it will render you depends entirely upon the attention and skill which you bestow upon it.

It often happens that after a man has dressed several bits he begins to think himself a bit dresser, and thus ceases to bestow on the work any more attention than is necessary to just dress and temper the bit at hand. If you find yourself beginning to think you know so well how to dress bits that you can not improve, then you haven't even begun to learn the first principles, as a man who is really beginning to understand, sees that there is a great deal more to dressing the bits than he can learn for a long time to come.

There are so many things to know, so many little kinks and ways to learn, many of them insignificant, yet in the end so highly important, that no tool dresser, no matter what his experience, can be justified in saying that he knows it all.

It is not the writer's desire to try to discourage you, but rather to make u realize the importance of the bit dressing end of the business, so that you do not neglect this part of the work through ignorance of its possibilities.

It will not require much time for you to learn to dress a bit so that it can be used for drilling, but do not stop content with this accomplishment. Study all the phases of the work, watch the different effects of different heats, see the effect caused by different kinds of fuel, try different methods of tempering, using first one color and then another; try the different shapes of bits on the different kinds of rock, note how different methods of hammering affect the steel; watch all the above points and the thousand and one other points which will arise, and you will find that you are not only engaged in a difficult work, but a very fascinating study. It will be impossible to tell in the space, which this book allows, many of the important characteristics of steel, and the writer would suggest that if you desire to inform yourself fully in regard to steel working, you purchase some good book on the subject which will not only give you the practical but the theoretical side.

For convenience in treating the subject, and to prevent confusion, it will be considered under four heads, as follows:

Making the Forge. Heating the Bit.
Shaping the Bit. Tempering the Bit.

**Making the Forge**—For heating bits of a size up to eight inches, a satisfactory forge can be made by simply digging a hole in the ground. For bits larger than eight inches, a forge with hood over top should be used.

To make a forge in the ground, dig a circular hole from 6 to 10 inches in depth and from 10 to 12 inches in diameter. The depth depends upon the character of the fuel to be used.

If a good grade of coking or blacksmithing coal can be had the hole need not be over 6 inches deep, but if coke or a coal of non-coking variety is used then it will be necessary to make the hole deeper.

The reason for making the shallow hole is that the coking coal runs together when heated, and thus if a very great thickness is placed above the tuyere iron the blast will be unable to get through and the top of the fire will be dead. On the other hand if coke or a non-coking coal is used, it will be necessary to make a deeper forge owing to the fact that these two kinds of fuel do not change their form until entirely consumed, and as they offer but slight resistance to the passage of the blast, it is necessary to have a deep bed of coals in order to keep the blast from blowing directly upon the bit.

With each Cyclone machine there is always included a blower, either belt driven or steam, for heating bits. The belted blowers are placed on all portable machines whether operated by steam or gasoline power, while the steam blowers are placed only on steam traction and the double walking beam types of drills.

## A No. 4 Cyclone Traction

Drilling Water Wells in North Dakota.

## A No. 4 Cyclone Traction

Making a rather risky move with derrick up.

## A No. 2 Cyclone

Used in shaft sinking operations by the Detroit Contracting Co.

Steam Blower.

In digging a hole for the forge, it should be so located that the 10 foot piece of linen air hose, included with the outfit, will just reach from the spout on blower to the end of tuyere iron. The hose is connected to the steam blower by slipping it over the piece of pipe which screws into the reducer on blower, but on the belted blowers the hose is slipped onto a tin elbow. The ends of hose should be securely fastened to the blower and tuyere iron by tying the respective ends with twine.

In connecting the hose from the blower to tuyere iron it should be stretched so that no kinks occur as these will reduce the force of the blast.

Belt Driven Blower.

The tuyere iron should be so placed that it comes at the very bottom of hole and should be so arranged that the blast does not concentrate at one point but diffuses itself as much as possible through all parts of the fire. Digging the hole something in the shape of a funnel, only more rounding at the bottom, will greatly assist in giving all parts of the fire an equal blast. Of course when the hole is deep and coke is used, this is not such an important point, as in the deep forge the air will have time to diffuse before reaching the center of fire, but as the even and equal heating of a bit depends greatly upon a diffused blast, no precautions should be omitted which will assist in obtaining this end.

To prevent the tuyere iron from becoming burned, all of it, excepting the air outlet, should be covered with dirt.

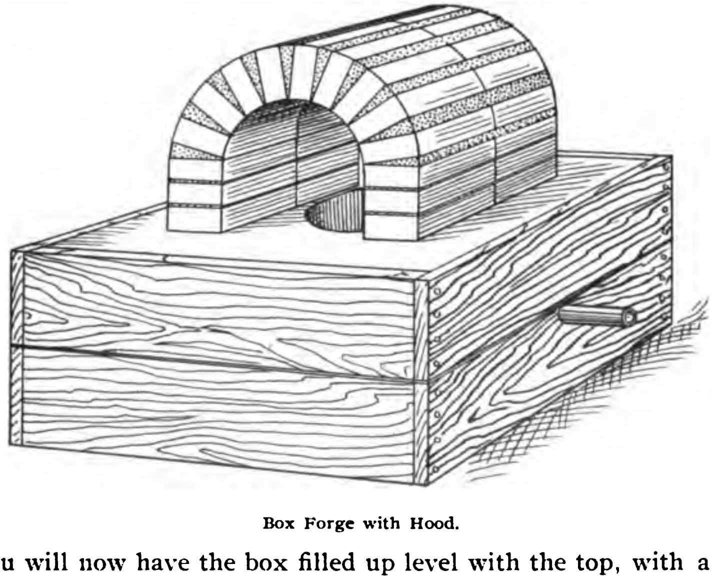
It sometimes happens that the forge has to be built on the bare rock, and when such is the case, it can be constructed by piling up rocks in the form of a circle, to a height of 5 or 6 inches and then plastering up the cracks between them with mud.

If you ever find it necessary to build such a forge do not use rocks which have lain in the water, or rocks which seem to be moist, as such rocks are liable to contain enough water to cause them to explode, when heated.

When bits 8 inches or above in size are to be dressed, coke should be used as fuel, and a deep forge, provided with a hood, should be employed. It is necessary to have the hood for the reason that the large bits can not be heated evenly unless some means is provided for keeping the coals both above and around the bit at the same temperature as the coals below.

While it is possible to use a forge built in the ground for heating large bits, yet, inasmuch as the heating of a big piece of steel is rather particular work, it is better to build a box forge with a permanent hood of fire brick, as this will prove far more satisfactory, especially if the hole to be drilled will require the dressing of many bits.

To construct a box forge, make a box 3 ft. x 3 ft. and 1½ ft. deep. In the center of one side of the box and 12 inches from the top, bore a hole 2½ inches in diameter. Through this hole insert a 2 in. pipe, running the pipe into the box until the end comes in the center of box. Now fill the box with clay, or dirt as near like clay as you can get it, until the box is filled up even with bottom of pipe. From this point continue with the filling, but leave a funnel-shaped opening from the end of pipe on up to top of box. The bottom of opening should be about 6 inches in diameter, and should taper outward to the top where it should be about 12 inches across. Pack the clay walls around this funnel-shaped opening so that the walls are smooth, and place enough of the clay on bottom to completely cover the pipe just leaving a space for the blast.



Box Forge with Hood.

You will now have the box filled up level with the top, with a funnel-shaped opening 12 inches in diameter in the center, this opening extending downward 12 inches, where it has a diameter of 6 inches, at which point it connects with the 2 inch pipe, which is to be used for tuyere iron.

Next lay a wall of fire brick 10 inches high on two sides of the opening, leaving the other two sides open. After the walls are built, construct a hood by securing some iron bars and bending them in an arch, over the brick walls and then cover them on the inside with fire brick. The hood should be high enough to clear the top of box by about 12 to 14 inches, and should be long enough to extend out past the hole in box about 4 inches on each end. The front of hood must of necessity be left open so that the bits can be placed in the fire, but the back end should be bricked up to within 3 or 4 inches of top, just leaving a space large enough for draft. A sheet iron shield is often used to cover front of hood after the bit is in place, and this assists in holding the heat on the bit, especially if the forge is in the open, and the wind is blowing into the hood.

After the box forge has been fired up two or three times, the clay walls become vitreous and thus stand firm as long as needed.

**Heating the Bit**—As it is necessary to know something about the composition of steel in order to understand why certain things should and should not be done, when steel is heated, we are including the following small amount of "Theory:"

In the manufacture of steel, the first step, after mining the ore, is the converting of the ore into pig iron. As the ore itself contains many impurities and as the molten iron picks up other impurities in the blast furnace, it is natural that pig iron should be very impure. As a rule pig iron contains from 90 to 95 per cent iron and from 5 to 10 per cent impurities; the impurities usually being carbon, silica, phosphorus and sulphur.

To transform this impure iron into steel it is necessary to burn out the impurities and for this purpose two kinds of appliances are in use; one known as the Bessemer converter, and the other the open-hearth furnace.

The product which comes from either the converter or the open-hearth furnace is very pure, ordinarily containing not over a few tenths of one per cent of impurities, the greater part of the impurities consisting of carbon, which is not injurious to the steel. In fact, it is very necessary that carbon be present if the steel is to be used for tool making purposes.

The presence of sulphur and phosphorus are, however, very injurious, the sulphur making the steel brittle when hot, and the phosphorus making it brittle when cold. You have probably heard the blacksmith say that this or that piece of steel is "hot short" or "cold short," which means that the steel has too much sulphur or too much phosphorus.

As different amounts of carbon in steel greatly affect its properties, and as steel makers have determined by careful experimenting what amounts of carbon should be used for producing different kinds of steel, it is the usual practice in making steel to first eliminate all the impurities, including even the carbon, and then while the steel is in a molten condition a pre-determined amount of carbon is added so that the per cent of carbon which the steel contains is absolutely fixed.

Steel which contains from ½ of 1 per cent to 1½ per cent of carbon, has the property of "taking a temper" or of being hardened and is known as tool steel.

While as a rule, a drill bit is made of two kinds of steel, one the soft steel used in the shank, and the other the tool steel used in the cutting end, we are in this chapter interested only in the cutting end of bit, and thus in speaking of steel, it will be understood that tool steel is referred to.

The first step in heating a bit, after building the forge, is to get the fire in shape. A bit should never be put into a "green fire" as not only will the steel be heated unequally, but the sulphur and other impurities which are driven off the fresh fuel will affect the steel.

To start the fire take some shavings or other inflammable material, and place it in bottom of forge, and after this has a good start place some kindling on top and turn on blast. To start with, the blast should be very light and this can be regulated to a nicety by placing a wrench or other article on the blower hose, and so regulating its position that just the required amount of air is allowed to pass. After the kindling has caught nicely, place a thin layer of fuel on it, and as the fuel begins to take fire, place on more of it, until the forge is completely filled.

If coking or blacksmithing coal is used, the forge will, of course, be shallow, and the coal should be heaped up several inches above the level. As coking coal "runs together" and is as a rule very fine, it will have a tendency to prevent the blast from passing, and thus it will be necessary, from time to time, to open up through the coal, passages for the blast. This is done by inserting the poker at different points and gently prying up the coal.

In inserting the poker, you will notice that the coal has coked into a solid mass, and you should so insert the poker that only the central part of the fire is disturbed, thus leaving a solid wall of heated coke surrounding the loosened up center. This center should be about 10 inches in diameter, and after all the coal which it contains has become coked, the fire is ready for the bit.

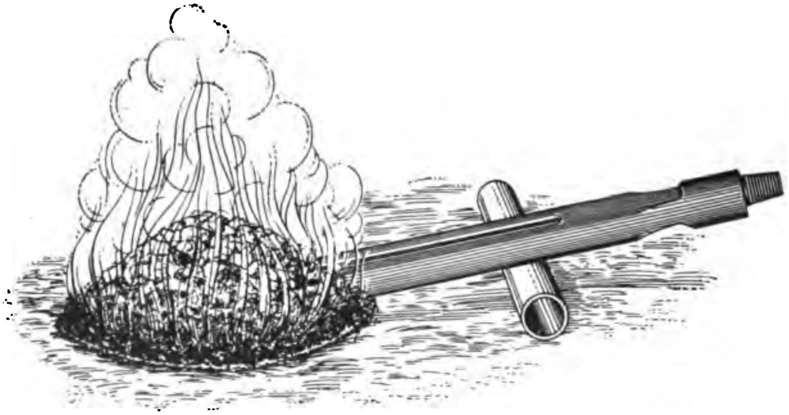
As, in starting the fire, the coal was piled up several inches above the ground, the coke will, therefore, be higher than the level of the forge, and one side of the wall should be cut down, so that it comes even with the level. If the center between the walls is 10 inches in diameter, the space cut in the wall should be about 8 inches across. Next rake all the coked coal out of center, down to the level of top of forge, and if the fire has been properly made and the poker judiciously used you will have a bed of hot coals about 6 inches deep and 10 inches in diameter covering the tuyere iron and above these coals and completely surrounding them, except where the open space has been cut out, will be a wall of hot coke about 4 inches high.

Now place the bit in the fire, first cleaning it off carefully so that no mud or cuttings adhere to the steel. The reason for cleaning bit is, that the cuttings may contain a large amount of iron pyrites and if this is allowed to remain on the bit, the action of the fire will liberate the sulphur which is in the pyrites and this will prove very harmful to the steel.

In putting the bit in fire, it should be placed through the open space in the coke wall, and the cutting edge of bit should extend about 3 inches past center of fire.

Care must be exercised in putting bit in fire, to see that it is not jammed through the wall, thus tearing up the fire, or pressed down against the coals with such force as to crush down the fire thus shutting off the blast.

If a bit 5 inches or smaller is being dressed, it can be easily managed, but for larger bits, unless a crane is used, a bit can be best placed in the fire by handling it on a roller. The roller used should be about 3 inches in diameter and about two feet long. While a roller made of wood is best, still one made from 3 inch pipe answers the purpose nicely.



Showing Ground Forge and method of using Roller.

To use the roller, place it about 2 feet from the fire and then lay the bit in the center of the roller, pointing the cutting edge toward the fire, and leaving the longer part of bit extend outward from the roller. Now by taking hold of pin, the bit can be rolled into the fire with ease and can be placed just as wanted. The roller should of course be placed so that the bit enters the fire through opening in coke wall.

If you are dressing bits in the winter time and the bit is very cold it should not be covered as soon as put in the fire, but should remain on top of the hot coals for five or six minutes and should be turned three or four times in order to slightly warm the steel before subjecting it to the full heat of the forge. After the chill has left the steel cover it with the coked coal which you previously scraped out of center of fire. If instructions have been carefully followed you will have more than enough of the coke for this purpose and this excess coke can be piled at one side for future use. After the bit has been covered, sprinkle a small amount of fresh fine coal around the edge of the coke just put on. By sprinkling on a small amount of the green coal from time to time the supply of coke can be kept even with the amount consumed.

After the bit has been heating for about ten minutes turn it over so that the other side comes next the fire. Leave it on this side until it comes to a dull red, then turn it back again, and leave it until the proper heat for dressing is reached. The reason for turning the bit is so that it will be heated evenly and uniformly, and if the fire has been properly built and tended, it will not be necessary to turn the bit oftener than advised above. However, it is very essential to have the bit evenly heated, and if you find it necessary to turn it several times to accomplish this result, do so, but it is best to turn the bit as few times as possible, in order not to disturb the fire.

It will be noted that the flame and smoke have a tendency to shoot back underneath the bit, and as this is caused by the open space afforded by the water channel, it can be remedied by placing some ashes or loose dirt underneath the bit, just at edge of fire.

Do not attempt to force the fire too strongly, as enough time must be given to allow the bit to heat evenly. On the other hand, do not give the bit more time than is necessary to bring it to a proper heat, and never allow the bit to "soak" in the fire after the proper heat has been reached.

The writer has often seen drillers cut down the blast of forge and allow the bit to remain in the hot coals for several minutes, after bit is hot enough to dress, with the idea that by so doing the steel would be in better shape to dress, owing to the greater amount of heat absorbed. Such practice is not only a waste of time, but is harmful to the bit, as the hot coals seem to draw the carbon out of the outer edge of steel.

The bit should be so placed in the fire that for 4 to 5 inches up from the cutting edge, it will be heated to the same temperature. Some bit dressers do not seem to think it necessary to heat the bit for more than a couple of inches on the end, but if this practice is followed, a cracked bit will invariably result as the steel will not be heated far enough back to allow the metal to "flow" under the heavy blows used in stoving back the edge. This point will be discussed under "Shaping Bit."

Owing to the fact that the corners of a bit are much thinner than any other part, and will thus heat much more rapidly, they must be carefully watched, to see that they do not burn. If the fire has been properly made so that it has an even temperature throughout, and if the bit has been properly placed in the fire, there is not much danger of burned corners, but if the fire is "dirty" so that the heat is not uniform, the proper heating of bit becomes almost an impossibility.

A "dirty" fire is generally the result of impurities in the fuel. If coal is the fuel, the impurities may clinker over the tuyere, or pieces of slaty coal may lie in the path of the blast. The action of the impurities is such that the blast is partially cut off, thus causing parts of the fire to be hot, while other parts are dead.

A "dirty" fire can also be caused by an accumulation of ashes or burned out coke.

If coke is the fuel used, the forge should be cleaned out perfectly clean after each heat; if coal is used the forge should be cleaned perfectly clean within the space surrounded by the coke walls.

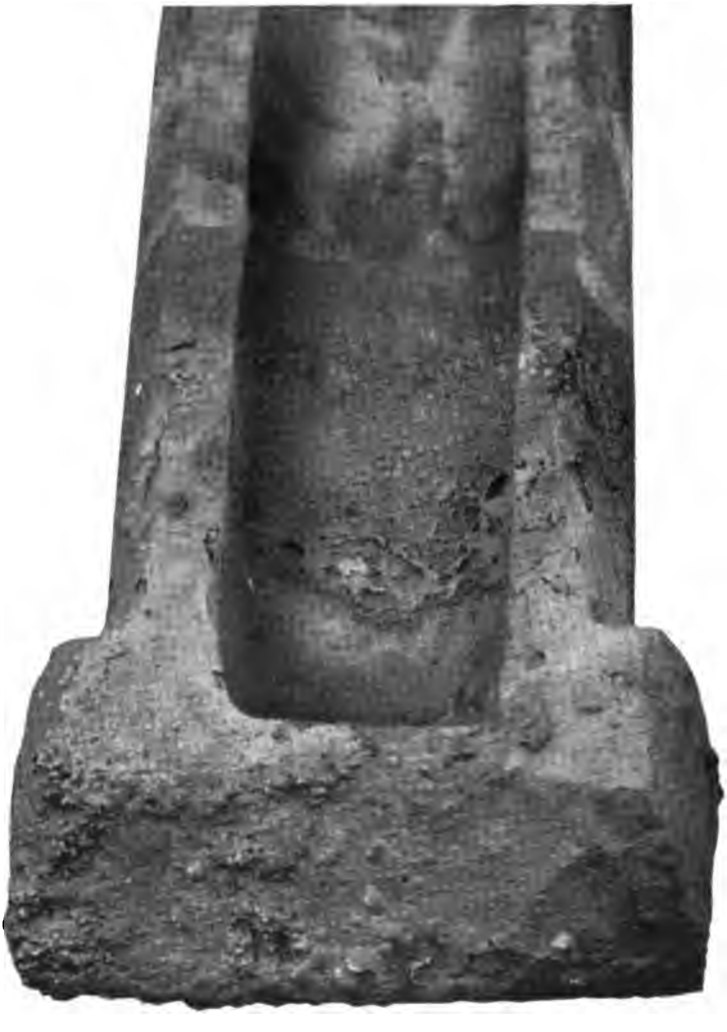
You will note, when cleaning out the forge in which coal is used, that there is quite an amount of small pieces of very hard coke. This coke should not be used over again, as it is more ash than coke and contains such a large amount of impurities as to be very injurious to the steel.

It must be your constant endeavor to keep the steel in the bits in the same condition in which it came from the factory, and to do this, it is absolutely necessary that no injurious foreign substances be allowed to come in contact with the steel while it is hot. Coal which contains sulphur is very harmful, but coal which contains phosphorus in any amount will completely ruin that part of bit which has been heated in its presence.

Another cause of spoiled bits, and perhaps the most prolific cause of all, is over-heating. It is possible to heat iron until the "sparks fly" without any injurious effects, but owing to the fact that bit steel contains carbon in comparatively large amounts, the heat which would be proper for iron would completely spoil steel, as at this high temperature the carbon would be burned out, and the steel made porous and brittle.

On the first few bits which you dress and until you have confidence in your judgment, it would be well to pay extremely close attention to the heating. If by any chance a bit should be burned, it is best to cut away the burned portion, as it is impossible to work burned steel and also impossible to temper it.

On page 73 is shown a cut of a badly burned bit. The photograph from which the cut was made, was taken as soon as the bit cooled down, and shows the steel "blisters" resulting from excessive heat. If these blisters be removed, by scraping, the steel will be found to be porous and spongy and full of small holes.



Cut showing appearance of Badly Burned Bit. By scraping away the steel blisters the steel underneath will be found to be spongy and brittle.

While the bit shown in cut has been so badly burned that the burn is easily detected, it sometimes happens that steel is burned so slightly that it is not noticed by the driller, and thus he goes on with the bit dressing wholly unconscious that he is working spoiled steel, and when after a run he pulls the tools out of the hole and sees the corners or edge of bit broken off, or ground away, his inclination is to say that the steel is no good.

Do not hastily condemn the steel. In nine cases out of ten, you will find that it is you who are to blame and not the steel which is at fault. On account of the conditions under which a well driller ordinarily has to work, it is an easy matter to burn steel, and thus you must use an extra amount of care in watching the bits while they are being heated.

If the direct rays of the sun fall upon the fire, you should have your helper so stand that he shades the fire when the bit is being examined, as a bit examined under the glare of sunlight never appears as hot as it really is. To satisfy yourself of the difference in appearance of heated steel when examined in the sunlight, and in the shade, you should secure a good sized piece of steel, a piece of old railroad rail will do, and experiment by making several heats under varying conditions of light and shade. Compare the appearance of the steel at certain heats in the sunlight and at the same heats in the shade, and you will thus realize the difference and will feel more inclined to be careful.

In selecting steel for bits, the manufacturer must steer a careful course between two extremes. If steel with a high carbon content is used, there will be great chances of having the bits spoiled by over-heating. If steel with a very low carbon content is used, it can be safely heated to a very high heat, but cannot be depended upon for taking a high temper. Besides the question of tempering, there is another point to be considered, and this is the dressing of the bits. If bits are made of extremely high carbon steel, they cannot be safely heated to a temperature that will admit of easy working, unless the very greatest care is exercised, and inasmuch as there is not one driller in ten that will, at all times, give his bits this exact care, and on account of the fact that a bit cannot be easily dressed, unless it is heated to a temperature at which steel will "flow" under the hammer blows, it has been found best to use a steel which can safely be heated to an easy working temperature and yet contains carbon enough to cause it to take a good temper.

As bits made by different manufacturers hardly ever contain exactly the same kind and grade of steel, it is a good policy to buy all of your drilling tools from the same concern, until you are convinced that you can get better elsewhere. By adopting this plan, you will become familiar with the correct method of working the steel which that particultar concern uses, and thus your results will be much more satisfactory than if you attempt to use several different makes of bits, which are almost sure to contain different kinds of steel.

A drill bit made of the proper kind of steel will admit of heating to a light "cherry red" without harm, for dressing purpose, but for tempering, should be raised to a lower heat.

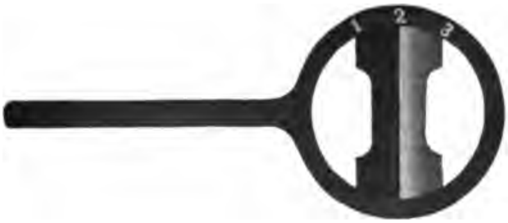
In starting with a bit of certain make, you should begin by heating the bit slightly higher than a medium dark "cherry red." On the next heat run it a little higher, and at each bit dressing continue to increase the heat until you have found the point at which the steel seems to work easily and yet stands well after tempering. Never, however, raise the heat above a light "cherry red" unless you have proven by experience that your judgment on heat will not mislead you.

Often the bits become dulled on the edge without wearing much out of gauge or without the corners being broken off, and where a bit in this condition is to be dressed, it should not be heated to more than a dark "cherry red" as no stoving is required, and the edge can be sharpened up and the corners filled out by light blows of an ordinary two pound machinists' hammer. These points will be discussed under "Shaping the Bit."

Another factor to be considered in regard to raising steel to a high heat, is the nature of the fuel used. Fuel containing impurities will prove harmful to steel at all temperatures above a dark red, but as the temperature of the steel increases, the harmful action becomes much more intense, so that a steel which could safely be heated to a light "cherry red" in a pure fuel would be ruined if heated much above a dark "cherry red" in the presence of an impure fuel. This fact must always be borne in mind when using coal or coke that you have not used before. If you have any doubt about the fuel, experiment by trying the lower heats first, and then gradually increasing the temperature at each bit dressing.

**Shaping the Bit**—To shape a bit quickly and accurately, it is necessary to have a thorough understanding of the functions performed by the various parts composing the cutting end and to know the relations which these parts bear to each other.

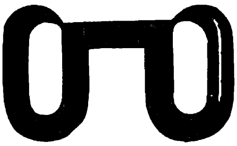
The parts composing the end of bit are as follows: The Cutting Edge, the Faces, the Corners, the Wearing Surfaces or Wearing Edges, the Shoulders and the Water Courses or Water Channels.



By referring to the accompanying cut, showing lower end of bit with bit gauge, the various parts are located as follows: The Cutting Edge extends from point 2 across the bit. The Faces extend outward from either side of edge. The Corners occur at 2 and the same point opposite. The Wearing Surfaces include the line bounded by 1, 2 and 3, and the same line on the other side of bit. The Shoulders are the part of bit extending upward from the two Corners and the Wearing Edges, and the Water Courses are the grooved spaces which cut into the faces and extend upward along the length of bit.

After bit has been heated to proper temperature, place it on the anvil block with one of the flat sides down.

If the bit is of small size one man can easily carry it from the forge to the anvil, but if bit is too heavy for this, it can be handled by two men, by placing a stick under center of bit, and allowing the ends to project so that they can be caught hold of. By grasping stick with one hand and the pin end of bit with other hand, the bit can be easily balanced. If the bit is of such size that it cannot be carried by two men, and no lifting device is at hand, it can be dragged from the fire to the anvil by placing the spectacles on wrench square.


Spectacles for Carrying Bits

Begin hammering by striking first at center and working outward towards the corners, the heaviest blows being used at center, and gradually growing lighter as the corners are approached. After hammering one side for a short time, turn bit over and go through same performance on other side. Repeat these operations until bit has been stoved the desired amount. Care must be exercised to see that one side does not receive more or heavier blows than the other, as any unequal hammering will result in throwing the cutting edge to one side of center, thus making the bit lop sided. Another point to be watched is to keep the cutting edge in a straight line and not allow it to become rounding. If the cutting edge becomes rounded it is impossible to get the same drilling speed out of the bit owing to the fact that the corners and the wearing edges cannot be made as sharp as if the cutting edge is kept in a straight line.

Another point to be watched is to see that the angle between faces is not too sharp, or too flat. If the angle is too sharp, it is impossible to put sufficient wearing surface on bit, and in hard rock drilling this is liable to result in a hole which is not perfectly round—as drillers say, a "flat" hole. On the other hand, if the bottom of bit is made too flat, the cutting speed is reduced. The correct angle to use varies according to the size of bit, and also the hardness and condition of the rock.

On a 3-inch bit, in medium hard rock, the angle is usually 90 degrees. As the bits increase in size the angle should become greater. Thus, on bits from 4 to 5 inches, the angle should be about 100 degrees; on bits from 5 to 6 inches, 110 degrees; from 6 to 8 inches, 125 degrees, and from 8 to 10 inches 135 to 140 degrees. The above angles are to be used when drilling in rock of medium hardness. If the rock is very hard or contains crevices, or is much broken, the angle should be made flatter.

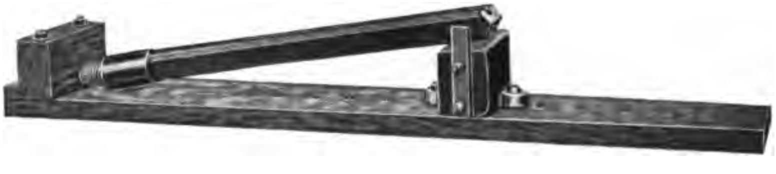
It is necessary to use the larger angles when drilling the hard rock in order to make the corners and cutting edge heavier. Sharp corners or a thin cutting edge will not stand well on hard drilling, and while their cutting speed, when first put in the hole, will be greater than the flatter bit, yet, owing to the fact that the heavier edge and corners will not break down nearly as soon as the thin edge and corners, the speed made by the flat bit will be greater, in the long run.

Not only will the flatter bit cut more feet in the same length of time, but, inasmuch as the corners stand firm the danger of the hole pinching down is not nearly so great. Should an attempt be made to run a thin bit the same length of time that a flat bit is run, on hard rock, a "pinched" hole will invariably result. This is a thing that should always be avoided if possible, as it will be necessary to ream the hole before the next bit can be used. Not only does the reaming consume much time, but what is even worse, it is a rather dangerous operation, as the tools are liable to become fastened in the hole. Using a flat bit on hard rock is following out the advice of the old saying, "Make haste slowly."

Where broken or creviced formations are encountered, a flat bit should be used, as a bit with thin cutting edge has a tendency to wedge itself in the cracks, and unless great care is exercised the tools will be deflected out of line and thus a crooked hole will result.

In order to be able to gauge the angle by eye, and thus make it unnecessary to measure it each time a bit is dressed, the bit should be supported on an anvil which is so arranged that it will hold the bit in the same relative position at each dressing. If this is done you will soon be able to judge very closely the angle being made, while the bit is being hammered.

For bits up to a size of 8 inches the handiest outfit yet devised for this purpose is the angle block and plank arrangement, shown in accompanying cut. You will note that this consists of a heavy plank having solidly bolted at one end, a wooden block against which the pin end of bit rests and at other end an iron block on which the heated end of bit is supported. The iron block is made with a backward sloping bevel, and is provided with lugs on either side, these arrangements being for the purpose of holding the bit solidly while it is being hammered. The plank is provided with holes every 2 or 3 inches along its length for the purpose of adjusting the position of iron block to correspond with length of bit being dressed. The block



Anvil Block and Plank.

should be so adjusted that the end of bit projects from 2 to 3 inches beyond its outer edge.

In stoving the bit, you will notice that not only is the width increased, but also that the metal around the points 1 and 3, and the same points opposite, (see cut page 75), are expanded. To prevent these points from becoming too wide apart, they should be hammered down frequently, during the stoving operation. Some tool dressers first finish stoving the bit before driving down these points, but this is bad practice for the reason that if the bit requires much stoving, the points become so much expanded that it takes considerable hammering to bring them into shape. This heavy hammering has a tendency not only to increase the width of bit, but inasmuch as the blows are such as to drive the metal back into body of bit, the cutting edge of bit is liable to be forced out of straight line. If the points are kept well worked down as the stoving is being done, the bit will shape up more symmetrically and with less labor. Another disadvantage of waiting until after stoving before driving down the points, is that as the points project quite a little from body of bit, they will cool rapidly, and if an attempt is made to drive these chilled points down into the hot steel, a cracked bit will invariably result. In bit dressing it should be your aim to so work the steel that the parts being worked are at the same temperature. You will remember that under instructions for heating the bit, you were instructed to heat the bit for a distance of from 4 to 5 inches on the end. This is for the purpose of raising all that part of bit which is to be hammered or which will be influenced by the hammer blows to the same temperature, so so that the steel will ''flow'' or move evenly and uniformly under the blows.

If you will stop a moment to think, you will readily see the harm which can be done by working steel which is heated unevenly. A piece of steel heated to a light cherry red will flow evenly and smoothly under a hammer; a piece of steel heated to a lower color is tougher and requires more hammering. If a piece of unevenly heated steel is hammered, the action will be as follows: The steel with higher heat will flow most easily and most rapidly. As long as this steel encounters steel which is as soft as itself, the only effect of hammering will be to force the grains more closely together, thus refining the steel. When, however, this soft steel encounters a streak of steel of a lower temperature, the soft grains will not mingle with the grains of the harder steel, and instead of the hammering refining the steel it will cause a crack or check to start where the soft grains are crushed against the harder steel. While, of course, this check cannot be seen, and may not manifest itself for some time, it is nevertheless there, and after the bit has been subjected to the strain of tempering several times, it will invariably show itself. There are often present in a bit dozens of these checks, caused by improper handling, and it sometimes happens that the checks become so numerous as to cause large chunks to spall off.

In stoving it will also be noticed that the steel is forced back into the water channels, thus increasing the thickness of the bit through the center. The water channels should be hammered down at the same time that the points referred to above receive attention. To reach into the hollow channels, it will be necessary to use the peen of sledge. Never allow the bit to become so thick through the water channels that it requires heavy hammering to reduce it, as much hammering at this point will force the middle of cutting edge outward, causing a rounding bit—as drillers say, the bit becomes "bellied."

Inasmuch as it is impossible, even by the most careful hammering, to wholly prevent an accumulation of extra metal around and in the water channels, it will be necessary from time to time to cut out and trim up the channels with a hot cut. In doing this work a hot cut having a half round edge should be used. If a cutter having a straight edge is used it will form sharp corners in the bottom of channels and these may later cause a crack to start in the steel.

Some drillers use a fuller, corresponding in shape and size with the channels, for driving them out, and the proper use of this tool makes it possible to keep the channels straight and clean.

If the channels are allowed to fill up the cutting efficiency of the bit is reduced, as a bit having a broad bottom will cause the tools to drop much slower, owing to the fact that the sludge in the hole offers great resistance to a thick bit. If the channels are kept clean and true the sludge has a chance to spread around the bit and thus the tools are free to drop.

If the bit being dressed is not much out of gauge and if the corners are not badly ground away or broken off, it will be necessary to stove it just enough to get the cutting edge in good shape. The amount of stoving required to fix up the cutting edge will be sufficient to spread the bit so that the corners and wearing edges can be sharpened up and brought to gauge.

If a bit does not require much work it should be heated but little above a dark cherry red and the dressing should be done by using light blows. A hammer weighing about two pounds is of nice size for such work. If a heavy sledge is used on steel in which the dark is beginning to show through the red, it will more than likely cause the steel to check. This is due to the fact that steel, when cooled to a certain temperature, will not flow under a hammer, and any attempt to shape it when in this condition, by using heavy blows, will result in crushing the grains of the steel.

As steel in cooling, cools from the outside, inward, there is first formed on the outside of bit a thin layer of steel which is at a lower temperature, and thus firmer, than the steel beneath. This cooling outer edge thus forms a sort of rigid shell completely enveloping end of bit, the shell increasing in thickness as the cooling progresses. It is now easy to see what would happen should the bit be heavily hammered while in this shape. The

Prospecting for Iron Ore in Virginia.

Drilling Water Wells in State of Washington.
Two types of Cyclone machines operated by separate power.

cooler grains of the outer film will not mingle with the more plastic grains below, and thus the only way the outer layer of steel can adapt itself to the heavy blows is by the crushing of the outer shell, an action which is bound to result in checks and cracks. If the bit has cooled far enough so that the shell is sufficiently thick not to break under the blows there is not much danger to be feared, but when this point has been reached the bit is so cold that it is a waste of time to try to hammer it.

There is now another side of the question to be considered. You will notice on page 70 that you are instructed to heat the bits so that they will be heated evenly, that is, so that all of the heated end will be at the same temperature.

You will now see the necessity for those instructions.

If a bit is heated so rapidly or in such manner that it is at a high heat on the outside and at a comparatively low temperature on the inside, and it is subjected to heavy stoving blows, the cooler and harder steel in the center of bit will act as a sort of wedge over which the hot steel will be forced.

This will result in the starting of a crack up through the center of bit, and inasmuch as a great strain comes at this point when the bit is being tempered, it will not take long before the steel will open up along this crack.

When the bit to be dressed is in bad shape, requiring much stoving, it should be heated to a light cherry red and heavy stoving blows used. The advantage of the heavy blows is two-fold—they bring results quicker and they refine the steel. The last reason is the more important and is explained as follows:

When steel is heated to a light cherry red, or in fact to any high heat, in becomes more porous owing to the fact that the grains are made coarser, and are thus forced further apart. If steel in this condition is allowed to cool, it will be found that the grains when cool are nearly in the same condition that they were at the highest temperature. In other words, a piece of steel, unless acted upon by some external force, has about the same structure when cold that it had when at its highest heat. This is an important point to be remembered and will be referred to later under "Tempering Bits."

Continue using the heavy blows until the bit has been stoved the desired amount, unless the stoving takes so much time that the bit begins to cool off considerably, in which case the blows should be lightened to correspond with the temperature of the bit.

The heavy blows on the hot steel force the grains closer together, thus making the texture finer and firmer.

Small bits, and bits which are in bad shape usually require three heats in order to complete the dressing. When such is the case, the first heat is generally used for stoving, cutting out the water channel and trimming up any part which shows signs of checking. The second heat is for turning down and shaping the corners and wearing edges, and finishing up the bit with a light hammer, while the third heat is for tempering.

If a bit is not in bad shape and is of sufficient size to hold a heat for some time, it can be dressed in two heats. The first heat being for shaping and the second for tempering.

Once in awhile it is possible to shape a bit and temper it in one heat, but it is doubtful if this is good practice. This point will be discussed under "Tempering Bits."

Sometimes it is necessary to dress a bit that is almost full gauge, which has a good cutting edge and has one good corner, but which has one very bad corner. This makes a mean bit to dress, for unless the bit is handled just right there is danger of having a low corner when the bit is finished.

Inasmuch as the metal to be used in filling the broken corner must be brought from the body of the bit by stoving, and inasmuch as this stoving will supply metal to both corners, the corner which is not broken off will, at the end of the stoving, have the most metal.

There are two ways to prevent this unequal distribution—one being to draw the steel towards the low corner by the way the hammering is done; the other being accomplished by cutting from the good corner enough steel to make the two corners the same.

The latter method is the easier but has the disadvantage of being a little wasteful of steel.

The hammering method depends upon the property which heated steel has of "flowing" under a blow. In order to force the steel towards the corner, the hammer faces are so inclined when the blows are struck, that the steel is forced towards the desired point.

A skilled tool dresser can easily fill out a broken corner without undue stoving of the bit, or without the bit being hammered out of shape, but if you are a beginner, it may require quite a little patience as it will probably be necessary for you to take several heats before the bit is finally shaped. If such should be the case, do not get discouraged as we have all had to pass through the same experience, and while the bit dressing end of the business may at first seem to you like a big thing, it will not take long, if you go at it with the determination to dig it out, before all parts of it will seem simple.

The writer does not mean to imply by the above that you can expect to become expert in ten days or two weeks, but that it will not take you long to learn the principles involved and after the few basic principles are understood, the rest of it is a matter of skill and this can only come with experience.

The amount of stoving to give a bit depends upon the condition of the same. If the bit is in fair shape, it requires but little stoving—just enough to sharpen the cutting edge and furnish sufficient metal to dress the corners and the wearing edges.

If such a bit is stoved a quarter of an inch over gauge it will usually be large enough for filling out all parts by the time it is brought to gauge.

On the other hand if a bit has a corner or corners in bad shape, it will be necessary to stove it quite a little over gauge in order to have sufficient metal to fill out the corners square and strong.

It is impossible to say just how much over gauge bits should be stoved owing to the fact that no two might be the same. However, it is very seldom that it is necessary to stove a bit more than one inch over gauge.

Do not stove the bit more than is necessary as it makes the finishing of the bit more difficult owing to the fact that it necessitates disposing of extra metal.

This extra metal must either be hammered back into the bit or else cut off, and this latter method causes a waste.

As stated before, one of the most important things to be learned in bit dressing is to know when the various operations have been carried far enough. When you reach this point, bit dressing will be an easy matter for you, as there will be no time lost in extra work, or no energy wasted in dressing up misshapen parts, It should be your aim first to dress a bit just as good as it can possibly be dressed, and next, to dress it with just as few blows as possible.

You can always tell when a tool dresser understands his business. There is no lost motion in his actions; he knows just how to heat, where to hit, how hard and how often to hit, and the rapid and businesslike manner in which he works, inspires confidence in his ability.

Nowdays the well drilling business is being conducted by men who are bringing brains as well as muscle into the work, and it should be every driller's desire to so inform himself about the various parts of the work as to make the business a profession, and not just a job.

To shape the corners, shoulders and wearing edges, after the stoving operation is completed, turn the bit on edge, shoving it out on the block far enough so that the shoulders will clear the outer edge.

If the bit is small, not over 5 or 6 inches, one man should hold it in the correct position while one man hammers it. If the bit is of larger size, it will have sufficient weight to hold it solid, and will be of such size that two men can hammer on it to advantage.

If the bit is in good shape with neither corner off, the first blows should be used for driving down the shoulders above the corners.

If the bit has been equally stoved so that both corners are equally distant from the center, then both shoulders must be driven down the same amount.

If, however, the stoving has been so done or the bit is in such shape that one corner is further removed from the center than the other, allowances must be made for this fact and the hammering so done that when the shoulders are both driven down, the corners will be equally distant from center.

While driving down shoulders try the size of bit frequently with the bit gauge, to see that you are not carrying the operation too far.

When the shoulders have been driven down so that the corners come to gauge, you have two fixed points from which to work. Now drive down the shoulder above the lines 1 to 2 and 2 to 3 (cut page 74) and the shoulders above the same lines opposite. This is for the purpose of forming the wearing edge.

In this operation, work from the corner outward. In doing this work the wearing edges on both sides of the bit should be brought down together. That is, the bit should be turned over several times during the hammering.

The reason for this is, that should one side be finished before starting on the other, the last side will not work easily, owing to the fact that it has cooled off considerably.

As the first part of the operation usually necessitates some heavy hammering, this should be done while the metal is at its highest heat.

Bring the wearing edges down until they come about 1/16 in. smaller than the gauge, while the corners come out full size. The reason for bringing the edges below gauge is that in driving them down the steel will be forced out past the faces of bit and as it will be necessary to drive this metal back into the bit, some allowance must be made for the expansion of bit, which will take place when this is done.

Now lay the bit flat as in stoving and shape up the wearing edges and the corners.

To drive the extra steel at these parts into the bit without undue expansion of the bit, the hammer should be so held that the blows do not fall directly upon the face but at an angle, towards the face. This will result in driving the steel away from the wearing edges into the body of bit.

After hammering the bit in this manner until the metal in the wearing edge is almost even with the faces, change the position of the hammer so that the blows fall the same as in stoving and continue until the edges are even with the face.

The bit should now fill the gauge exactly, but should it be a little large, due to the operation just described, it can easily be trued up by slightly driving down the edges.

The bit should now be about a dull red or a little cooler and is in excellent shape for the final hammering.

Take a small hammer, 1½ to 2 lbs. and go over the cutting edge, wearing edges and corners, using light blows, but many of them. This sort of hammering, when the steel is at a dull red or little lower heat, makes the bit stand better as it seems to make the grain firm and tough.

The instructions given above are for a bit which was not hard to dress.

For a bit in bad shape, the treatment is about the same excepting that it will have to be stoved more and thus will require more driving down on the shoulders. Shoulders on a bad bit are usually driven outward at the same time they are driven down.

To do this, the hammer is so held that the blows fall behind as well as down on the shoulders. This will result in setting the corners out at the same time that they are being driven down to gauge.

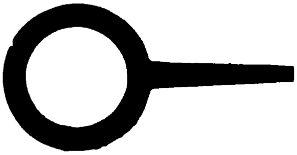
If a bit is in bad shape and requires much stoving, it should be reheated before shaping up the corners, unless it is a large bit which holds heat well.

It sometimes happens in making up a corner that cracks will come in the steel just at the corner and if these are deep they should be cut out. If they are not deep, you can neglect them, as the corner on which they are will probably come off in the hole.

In gauging a bit the bit should fill the gauge as shown in cut page 75. Also the bit should be so dressed that the gauge will pass up the bit freely. What is meant by this is, that the shoulder above corner and wearing edges should not project beyond the line of the corner and edges.

It is always best to use a bit gauge in gauging a bit, as with any other appliance, such as callipers, etc., it is easy to get the bit out of shape.

As the angle between the faces of a bit should vary according to the kind and hardness of the material being drilled, so also should the shape of corners, shoulders and wearing edges vary. In a hard formation the corners should be made rather flat and the shoulders should extend straight upward from the corners for a distance of about an inch. The wearing edges should also be protected by having shoulders extend above them. The purpose of the big shoulders is to give strength to the corners and edges by backing them up with metal.



Bit Gauge.

Heavy shoulders and wearing edges should also be used in sand rock drilling even though the rock is not hard, owing to the rapidity with which sand rock will wear the steel.

A bit with sharp corners and thin wearing edges, while it may not dull if used in soft sand rock, will nevertheless soon wear out of gauge.

In drilling in soft shale or slate, a bit of different shape should be used. Owing to the softness of this class of rocks the drill bit will slightly bury itself at each blow and if bit with heavy shoulders is used, it will constantly be wedging itself in the hole.

Instead of heavy shoulders, the shoulders should taper backwards from the corners, and the wearing edges should be dressed out thin. This is called putting a "feather edge" on a bit.

In rock much broken and fissured, the bit should not only be provided with heavy shoulders and wearing edges, but should be dressed with very full wearing edge. That is, the bit should be dressed so that the wearing edge fills a large part of the circle.

This makes the bottom of bit have somewhat the appearance of a reamer. To dress a bit this style, the angle between the faces, in stoving, is made very flat and the stoving is continued until the bit is considerably over guage.

In driving down the corners the extra metal is carried from the corners down and around as previously described.

In dressing a bit for gravel, sand or clay drilling, it should have an angle of from 70 to 75 degrees between the faces and should be dressed without much wearing edge.

A regular rock bit used in sand, clay or gravel makes slow drilling as the bit is so blunt that it packs the material in the hole without mixing it with the water.

Of course, when boulders are encountered in this material, it is necessary to use a rock bit as the cutting edge and corners of the gravel bit are too thin to stand up to hard drilling.

On page 87 are shown cuts illustrating three bits. A and B were made from two bits sent to the factory to be repaired and show very clearly the manner in which some drillers take care of their drilling tools. It would perhaps surprise many good drillers to know the great number of such bits we receive. It speaks mighty well for the profitableness of the drilling business when men who take such care of their outfits as shown by the above bits can continue in the business and make money.

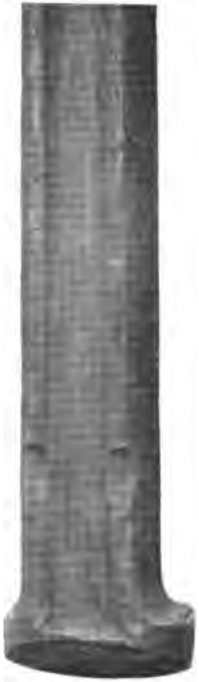
Bit "A" shows clearly that the man who dressed it did not have the least conception of what a bit should be or else was too lazy to put his knowledge into work. The bit shows about every defect in the catalogue excepting that it isn't cracked, and this is probably due to the fact that the man was too lazy to hit it hard enough to start a crack.

You will notice that the cutting edge is rounding, thus making blunt corners. One corner is further from the center than the other, a condition which will put an extra strain on the tools, owing to the fact that the tools are forced out of center line of hole. There are no wearing edges, and last, but not least, the water channels are filled up.

A driller with a bit shaped as this bit, would only drill about one-third as many feet per day as a driller with a properly dressed bit, even though all other drilling conditions were the same.

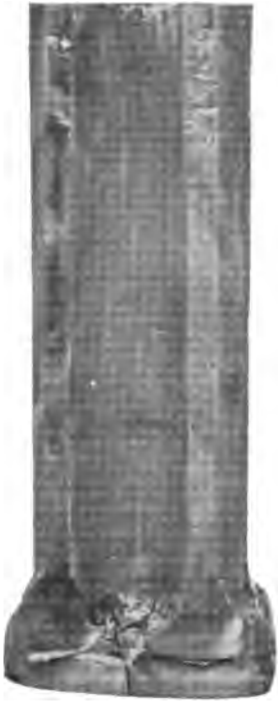
Bit "B" shows the result of unequal heating and deep tempering. The crack through the center has been started by hammering the bit while the steel was hotter on the outside than on the inside, and enlarged by setting the bit too deep in the water when tempering.

A



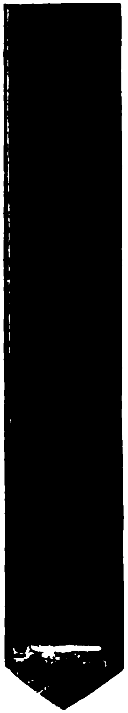
Caused by ignorance or carelessness.

B

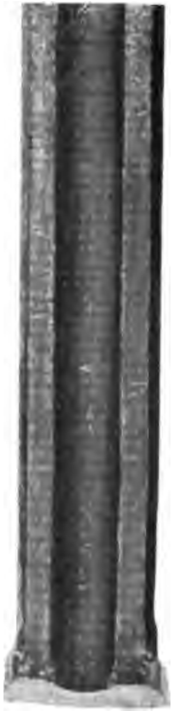


Caused by unequal heating and too deep tempering.

C



D



A 5-inch bit well shaped for hard rock drilling. Deep corners, heavy shoulders, full wearing edges, and clean water channels.

The steel in "A" is in fairly good condition and the bit, after shaping up, can be used, but the steel in "B" is ruined for a distance of about 8 inches up from the end.

The cuts marked "C" and "D" are different views of the same bit and show how a bit should look when properly shaped. This bit was dressed for hard rock drilling and you will notice the straight cutting edge, the deep corners, heavy shoulders, full wearing edges and clean water channels. This is the shape of bit which, when properly tempered, will make money for a drill man.

A well dressed bit will not only make you more money, but it will make your work much easier, as a bit when properly dressed will run longer than one poorly dressed, will be easier to dress when it becomes dull and most important of all, it will keep the hole in such shape that no reaming is necessary and thus the chances for fishing jobs become very slim.

**Tempering a Bit**—There are two methods of tempering a bit. One is to heat the bit to a certain heat, set it in water to a certain depth and leave it there until it is cold. This is known as tempering by quenching.

The other method, and this is the most satisfactory, is known as drawing the temper and consists of heating the bit to a certain temperature, then cooling the end by allowing it to stand in shallow water for a few minutes, after which the bit is withdrawn and the heat allowed to "run" until the cutting edge and the steel for a distance of from ½ to ¾ of an inch above the cutting edge are at the proper temperature, when the bit is set back into the water and allowed to cool. We will first consider this method.

Heat the bit for a distance of from 3 to 4 inches on the end, to a dull cherry red. For tempering never heat higher than this, and with some steels you will find it necessary to heat to even lower temperature.

The higher heats have a tendency to cause the steel to check.

Another disadvantage of the higher heats is that the texture is made coarser, and, as the grains of steel will be in the condition in which they were at the highest heat, it is necessary to temper at low heat, in order to keep the steel close grained and tough.

For the reason just given, it is imperative that the tempering be done on an ascending heat, that is, the steel should be brought to the proper heat and then set in the water, not raised to a higher temperature, then taken from the fire and allowed to cool down.

It is also necessary that the bit be brought to a heat slowly and evenly so that the metal all through end of bit will be as near as possible at the same temperature. To accomplish this it is best to heat with a "slow" blast.

The vessel for holding the cooling water is usually made in the form of a box about 1½ feet long, 8 inches wide and 6 inches deep. The lumber composing it should be at least 1 inch stuff, as the box will be subjected to pretty hard usage.

Two pieces of pipe 1½ inches in diameter should be run lengthwise through the box and so spaced that their centers are 3½ inches apart. The bottom of the pipes should come about 1½ inches above the bottom of the box and the pipe should be fastened firmly in the ends of box. The pieces of pipeshould be spaced equal distance from the center.

Now fill the box to within 2 inches of the top with clean, clear water. After the bit has been brought to the proper heat, set it in the water, so placing it that the cutting edge goes down between the two pipes, thus allowing the bit to be supported on its two faces by the pipe.

Some drillers use a flat iron plate in the bottom of box for supporting the bit but this is bad practice. Not only does this allow the cutting edge to come in contact with all the sediment which naturally settles on the bottom, but the iron plate seems to draw the temper out of the cutting edge, thus making it soft.

The pipe arrangement is by far the most satisfactory as it keeps the bit off the bottom and holds it up in such a manner that the water can circulate around all parts of it.

The water in box should be deep enough so that it just about comes to the top edge of bit faces. While the bit is cooling, keep the water around it in slight motion by stirring with a stick. This for the purpose of assisting in cooling by forcing the film of steam or bubbles away from the surfaces and is also for the purpose of varying the line of contact between surface of water and the bit.

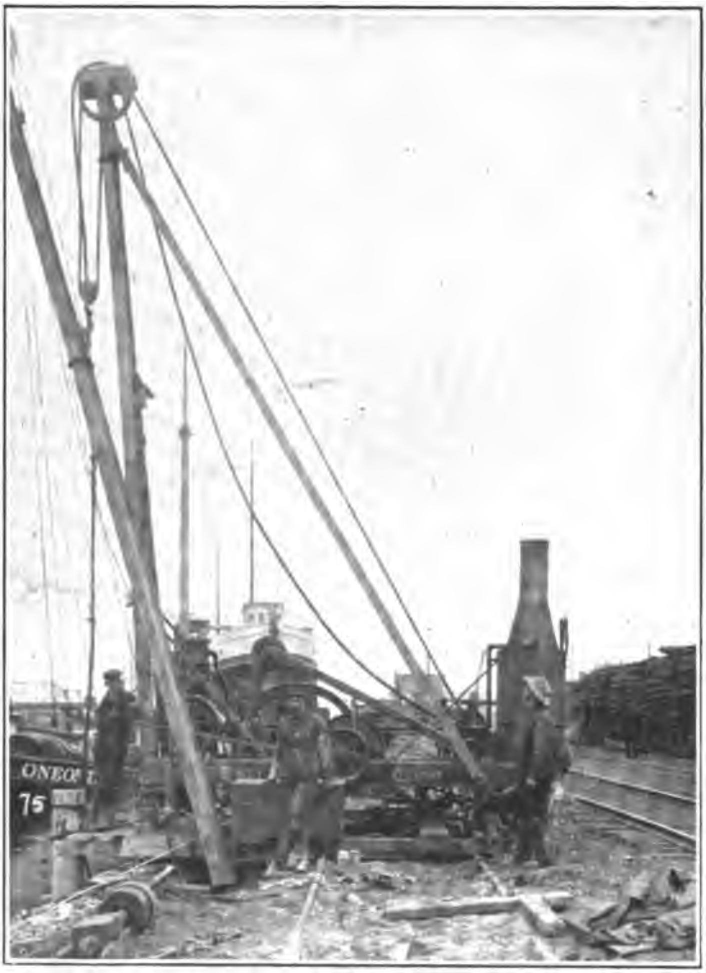
If the water is allowed to remain at a stationary level, it has a tendency to cause checking, due to unequal contraction of the steel.

While the operation of tempering necessitates the comparatively rapid cooling of the steel after it has arrived at a certain temperature, this cooling should be done in such a manner that the steel is given a chance to adapt itself to the change.

Do not set a bit deeper than the top edge of faces and if it is possible, temper by setting shallower. Never temper by shoving the whole heated end under water. This sort of action is bound to result in a cracked bit, if the bit is made of steel, and the better the steel the sooner will the cracks show up.

In tempering, the steel on outside of bit is cooled first. This results in forming a shell of cooling steel, which as it cools, contracts. As it contracts, it squeezes the metal in center of bit and this squeezing has a tendency to raise the center to a still higher temperature and this in turn has a tendency to expand the metal in center.

Thus two forces are at work, the cooling outer shell trying to contract and the heated inner metal trying to expand. You can now easily see how



A Cable Machine used for special work along Cleveland, Ohio, harbor front.

checks or cracks started in the heating or hammering of the bit will open up on tempering. Even when the bit is set shallow in the water, a great strain is thrown upon, or rather within, the steel, and should the whole heated end be shoved under water, the strain becomes enormous.

To return again to the tempering. After the bit has been sitting in the tempering trough for about two or three minutes, remove it from the water and with a brick or sandstone, scour the shoulders until they are bright. Now watch for the colors as the heat from above forces them down. The first will be a light straw color, then a full straw color, a light brown, a duller brown, brown with purple spots, light purple, dark purple, light blue, darker blue, blue tinged with green and so on. Each color represents a certain degree of heat and the following table shows the small differences in heat which it takes to run the full color list:

| | | | |
|---|---|---|---|
| Light Straw Color | 430 | degrees | Fahr. |
| Full Straw Color | 460 | " | " |
| Light Brown | 490 | " | " |
| Darker Brown | 500 | " | " |
| Brown fading into Purple | 510 | " | " |
| Light Purple | 530 | " | " |
| Dark Purple | 550 | " | " |
| Light Pigeon Blue | 570 | " | " |
| Darker Blue | 600 | " | " |
| Blue with Green | 630 | " | " |

For rock of medium hardness the temper should be stopped somewhere between the full straw and the darker brown. For extremely hard rock, temper to a little deeper color in order to give toughness to the steel. In very soft rock such as shales, a hard temper can be used, inasmuch as the shale is so soft that no great strain is put upon the edges and the hard temper will prevent the bit from rapidly wearing out of gauge.

In sandstone or other hard rock, it is best to temper as hard as possible and yet have the steel tough, in order to keep the bit to gauge as long as possible.

The colors recommended above will vary somewhat with the particular kind of steel used and thus the driller will have to experiment to determine just the proper colors to use for the bit which he has.

As the running of the colors depends upon the formation of an iron oxide, which forms as the heat travels through the steel, it is necessary that the water in which the tempering is done be perfectly clean and also that no oil be present, as dirt or an oil film will make the colors show up different.

It sometimes happens that steel will crack in spite of all you can do and in tempering this kind of steel, the water should first be heated almost to the boiling point. Some drillers use special solutions as cooling mediums, but it has been the writer's experience that these are more troublesome than beneficial.

If it is desired to use a quick cooling solution, the handiest and safest is a solution of common salt and water. This solution does not produce poisonous fumes and has the added advantage of being cheap and easily obtained.

If it is desired to temper by the "quenching" method, as referred to in the beginning, all that is necessary to be done is to heat the bit to the proper temperature, then set it in the water and leave it to cool.

The proper temperature to which it should be heated depends upon the hardness of the rock being drilled, also the kind of steel used and can be determined only by experiment.

The instructions given above in regard to too rapid cooling, unequal contraction, etc., apply with equal force to the present method of tempering.

The quenching method is all right for rock of medium hardness or softer, but for rock of great hardness, it is necessary to draw the temper in order that you may be sure the steel will stand.

The writer realizes that the subject of Bit Dressing has been drawn out to a length that may prove tedious to you on first reading, but the subject is so important, and has such a direct bearing on your success in the drilling business that it should not be slighted.

A great deal more space might profitably be devoted to this end of the business without exhausting its possibilities and the writer has attempted to embody enough theory and give sufficient reasons for his instructions so that you would understand the basic principles and thus be in a position to reason out any new problems which may arise.

If some new knotty problem comes up and the steel acts in a way which is seemingly altogether unexplainable, do not give up and excuse yourself by saying that the steel is at fault. It is true, there is a possibility of the steel being bad, but the chances are a hundred to one against it.

Set yourself to work to figure out the cause of the new condition and if you are successful and can locate the reason you have made yourself that much stronger, as the problems which you reason out yourself will remain with you long after instructions and rules have been forgotten.

In bit dressing, remember that while "The driller makes the well, the tool dresser makes the hole."

# PART III.

## Drilling Tools.

The descriptions of drilling tools which we have already given have been of a rather broad nature, it being the intention of the writer simply to show them in relation to drill work in general.

In the present chapter we will consider the tools with relation to weight, size, etc.

It has been found by experience that certain sizes of tools are best adapted for certain kinds of work. That is, the tools must be proportionate to the work to be done.

While it is readily apparent that a heavy string of tools will drill faster than a light string, still, owing to the fact that a heavy tool equipment requires a heavy machine, and inasmuch as in water well drill work the wells in the large majority of cases do not extend to a great depth, the weight of the drilling tools must be brought down to a point where it will not be necessary to have an unwieldy machine.

As an example: It would not be a paying proposition to use a heavy oil well rig on 200 to 300 ft. jobs, as the expense of moving, setting up and operating the big machine would eat up the profits to be made on the shallow holes.

Another point to be considered is the proper proportion of different parts of a tool equipment. By this is meant the proper proportion of joints, wrench squares, collars, shoulders, etc. These are points which cannot be figured by any fixed rules and can be determined only by experience in the field.

The dimensions which are given in the following pages are such as have been settled upon as best by a large majority of drill manufacturers.

**Rope Sockets**—Rope Sockets are made in many different styles, but the four styles illustrated are the ones now almost universally used.

The Patent Socket is fully described on pages 10 and 11.

The Wing Socket was one of the first sockets used and is still employed by many drillers for handling small tools.

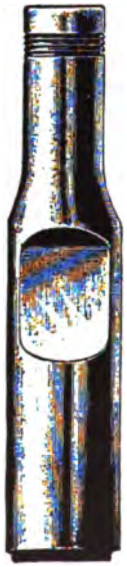
For large tools, however, it is not to be recommended owing to the fact that much time is required to "set" the rope, and also owing to the fact that unless great care is used the rope will be set crooked, due to the fact that the wings are not driven up even.

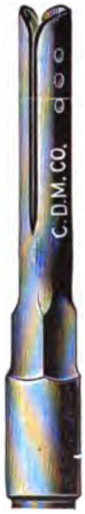
In setting the wing socket, the shank of the wings is heated and the wings slightly spread. The cable, after being wrapped, is pushed to bottom of opening, then the wings are driven together as far as possible and pins driven through and riveted.

In riveting, the heads of rivets should be driven flat, so that in case of fishing job they will not interfere with the action of the slips in fishing tool.

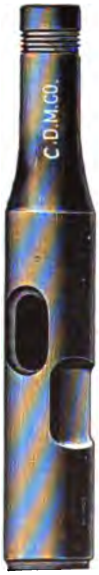
The New Era Socket, or as it is sometimes called, the Woodpecker Socket, due to peculiar shape of hole in side, makes a very handy socket owing to the fact that a rope can be easily and quickly "set." In this style socket the cable is pushed down from the top and comes out the beveled hole at side, then knotted as described on pages 10 and 11, and pulled taut, the bevel holding the cable without pins.

The New Era is used quite extensively in the oil fields, but it has one weak spot and thus must be watched closely at this point. Owing to the shape of bevel the rope is drawn against sides of opening with great force and this wedging action often results in starting a crack at edges of opening where the metal is thin.

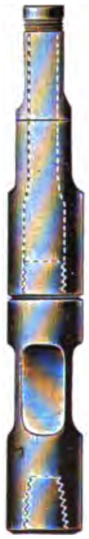

**Patent Socket**



**Wing Socket**



**New Era Socket**


**Sub Socket**

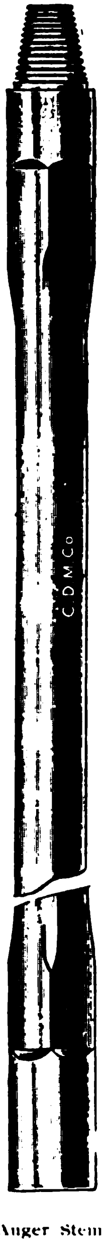
The Sub Socket is made to combine the strength of the Patent Socket with the convenience of the New Era Socket. By referring to the cut, its construction will be readily understood.

By using the straight pin it is possible to make the bottom of bevel the same size as the box, thus allowing the knotted cable to be easily drawn in.

Owing to the extra work required in making the sub socket, it costs quite a bit more and thus is not generally used.

It will be noticed that the top of the Patent, New Era and Sub Sockets have grooves cut around them. These grooves are for the purpose of making the fishing tools take a firm hold, in case it is necessary to use them.

It is the usual practice to make the hole through socket ¼ inch larger than the rope for which it is intended. Thus if the rope to be used is 1⅝ inch, the hole should be 1⅞ inch. This is done to allow plenty of room for inserting the rope, as a rope when new is generally somewhat over-size.



Auger Stem.

## Auger Stems and Sinker Bars.

The difference between an auger stem and a sinker bar is simply a difference in length.

In the oil fields any stem under 18 feet is called a sinker bar. On small portable rigs designed for water well drilling, this distinction is not made, as an 18 foot stem is a large stem for some of these small outfits.

In figuring on stems for different sizes of holes, the stems must be small enough to allow of sufficient clearance so that the tools will drop free, and yet be large enough so that the joints used will be of ample strength to stand all strains.

The strains thrown on joints are not great in small holes unless the hole goes crooked or a slanting crevice is struck or slanting strata are encountered.

If, however, a small stem is used in a large hole, the oscillation of the tools will be so violent as to throw an unsafe strain on the joints, especially the joint at bottom of stem.

There is also danger of a hole drifting, or becoming crooked when a small stem is used in a hole of large diameter. This drifting tendancy is due to the fact that the top of tools has such a large amount of play that the bit can easily follow the path of least resistance. Increasing the length as well as the size of stem will assist in overcoming this drifting tendancy. In the oil fields, where it is often necessary to start with holes 13 to 16 inches in diameter, the stems used are usually about 45 feet long. By using the long stems, the oscillations of the top of the tools have but little effect on the bit.

In making stems the joints are usually welded on, on account of the fact that the diameter of the collars of the joints should be greater than the diameter of the stem. Some few drillers insist on using a stem with a diameter the same size as the joint collar, in order to get as much weight as possible, but under ordinary drilling conditions this is not good practice as the stem will drag in the hole.

The following table gives the diameters of stems usually used on portable rigs in holes of different diameters, together with the sizes of joints and collars, as well as weights per foot of stems of various diameters:

| Smallest hole to be used in Inches | Diameter of Stem Inches | Size of Joint Inches | Diameter of Pin Collar Inches | Diameter of Box Collar Inches | Weight per foot of Auger Stem Pounds |
|---|---|---|---|---|---|
| 3 | 2½ | 1⅛x1¾ | 2⅜ | 2 7/16 | 17. |
| 3½ | 2¾ | 1⅜x2 | 2 13/16 | 2⅞ | 20.5 |
| 4 | 3 | 1⅝x2½ | 3¼ | 3⅜ | 24.3 |
| 4¼ | 3¼ | 1⅝x2½ | 3½ | 3⅝ | 28.3 |
| 5 | 3¼<br>3½<br>3¾ | 1⅝x2½<br>or<br>2x3 | 3½<br>4⅛ | 3⅝<br>4¼ | 28.3<br>32.9<br>37.7 |
| 5⅝ | 3½<br>3¾<br>4 | 2x3<br>or<br>2¼x3¼ | 4¼<br>4½ | 4⅜<br>4¾ | 32.9<br>37.7<br>42.7 |
| 6 | 3½<br>to<br>4¼ | 2x3<br>or<br>2¼x3¼ | 4¼<br>4½ | 4⅜<br>4¾ | 32.9<br>48.3 |
| 6¼ | 3½ to<br>4½ | 2x3 up to<br>2½x3½ | 4¼<br>5 | 4⅜<br>5¼ | 32.9<br>53.4 |
| 7⅝ | 4 to<br>4¾ | 2x3 up to<br>3x4 | 4¼<br>6 | 4⅜<br>6¼ | 42.7<br>59.3 |
| 8 and 8¼ | 4<br>to<br>5 | 2x3<br>up to<br>3¼x4¼ | 4¼<br>6¼ | 4⅜<br>6½ | 42.7<br>66.4 |
| 8¼ or larger | 4½<br>to<br>5½ | 2½x3½<br>up to<br>4x5 | 5<br>7 | 5¼<br>7⅜ | 53.4<br>80.9 |

You will note in the table just given nothing was said about length of stem.

The following table shows the lengths of stems usually used on portable rigs in holes of average size and different depths.

| Length of Stem Feet | Depth of Hole Feet | Length of Stem Feet | Depth of Hole Feet |
|---|---|---|---|
| 12 | 150 | 16 to 18 | 600 to 700 |
| 12 to 13 | 250 | 18 to 20 | 700 to 900 |
| 12 to 14 | 300 | 20 to 24 | 900 to 1200 |
| 14 to 15 | 350 | 24 to 26 | 1200 to 1600 |
| 14 to 16 | 400 | 26 to 32 | 1600 to 2000 |
| 14 to 16 | 450 | 32 to 45 | 2000 to 3500 |

You will note in the large table on opposite page that the measurements given for different sizes of tools are made with reference to the smallest hole in which the tools are to be used.

The table is drawn up in this manner for the reason that small tools which are ordinarily used for small holes are sometimes used for drilling larger holes and while the small tools will not handle the large holes so satisfactorily as tools of proper size, still there is nothing about the small tools except the slowness and danger of their operation which will positively prevent their being used in holes of a diameter larger than that for which they are listed.

Thus by referring to the table you will see that for drilling a hole 4½ inches in diameter, a stem 3¼ inches in diameter is the largest which can be used. That is, if a larger stem is used, it will drag in the hole and the drilling speed will thus be reduced.

On the other hand, there is nothing to prevent the 3¼ inch stem from being used in holes 5, 5⅝, 6 inch or larger in diameter except the fact that it will drill slower and, owing to its smallness, will allow the tools more play in the holes, thus being liable to cause trouble.

You will note that for drilling a hole 5⅝ inches in diameter, three different sizes of stems are given, namely 3½, 3¾ and 4 inch, also two different sizes of joints. The meaning of this is that a stem having any one of the diameters given above can be used for drilling a 5⅝ inch hole, it also being optional with the driller whether 2x3 or 2¼x3¼ joints be used.

It is the usual practice, however, to use 2x3 joints in 5⅝ inch holes except when deep holes are being drilled and thus long stems used, and except when the material to be drilled is extremely hard and greatly creviced.

Under either of the above conditions it is best to use the larger joints.

You will also note that as the holes become larger, the range in diameter of stems, and sizes of joints becomes greater. Thus for holes 8 or 8¼ inches, the stems to be used can safely range from 4 up to 5 inches and the joints to be used can vary between 2¼x3¼ and 3¼x4¼.

Owing to the wide range of sizes of stems and joints which can be used in holes of large diameters, the factor which usually determines the proper size of stems and joints, is the length of stem.

Thus in deep holes, where as a rule long stems are used, it is necessary to have the stems of large diameter in order to prevent excessive vibration, and it is also necessary to use large joints in order to stand the strain put upon them by the great weight.

On the comparatively shallow holes, up to 300 or 400 feet, where the stems used do not exceed 14 feet in length, the proportioning of joints to size of hole is not of so much importance, as the weight of tools is not so great.

However, even on the shallow work, the writer would advise that the proportions given in table for holes up to a diameter of six inches be followed very closely, as then, if it is wanted to drill larger holes with the small tools, the proportions will admit of quite a bit of what might be termed overload.

Thus if a stem 3½ inches in diameter by 14 feet long having joints 2x3 is being used for drilling 5 inch holes it can also be used with comparative safety for drilling holes as large as 6 or 7 inches in diameter, also if a stem 4 inches in diameter by 14 feet long, having joints 2¼x3¼ is being used for drilling holes 6 inches in diameter, it can with comparative safety be used for drilling holes 8 to 10 inches in diameter.

When, however, the holes are as large as 10 inches it is best to have a heavier stem with larger joints and the writer would not advise the taking of contracts for 10 inch wells if the work is to be handled with a stem no larger than 4 inches by 14 feet, unless the material to be penetrated is very easily drilled.

You will note in the table given at bottom of page 96, the lengths of stems recommended for holes of different depths. These lengths are figured as per the explanations given on pages 93-95 and are for holes of average size.

What is meant by average size, is holes ranging from 3 inches up to 8 or 8¼ inches in diameter. Holes of larger diameter demand extra long and large stems for the reasons given on page 95.

The two tables given on page 96, taken in connection, will indicate very clearly the proper size of stem to use for any depth or size of hole, the dimensions given having been found to be best by actual experience.

Thus, if the wells in a certain section of country average about 400 feet in depth and range around 6 inches in diameter, the tables would indicate that a stem 14 feet long by 4 inches in diameter, with joints 2x3 or 2¼x3¼ should be used.

If the same size hole is to be drilled to a depth of from 700 to 900 feet, the stem should be from 18 to 20 feet long, and so on.

After the proper size of tool equipment has been determined, the selecting of a suitable drilling machine becomes a matter of adapting machine to equipment. It is here that the advice of the drill manufacturer must be relied upon, and thus it behoves every purchaser of a drilling machine to make sure that the company with whom he is dealing is in charge of experienced drill men whose advice will be based on practical field work.

It is true that it is possible to make a small amount of hole with any kind of an outfit, but the writer is basing his advice on the theory that drill men desire to make the greatest possible amount of footage.

## Drilling Jars.

The making of a good set of drilling jars is one of the most particular jobs which a drilling-tool manufacturer has to face. Owing to the heavy strains which are thrown on the jars, it is necessary that no flaws nor imperfections be allowed to enter into their construction as these are bound to show up sooner or later by causing a fishing job.

Jars are made up of two classes of steel; the soft steel used in joints and the hard steel used in reins and heads. The steel used in reins and heads is practically the same as used in the cutting end of bits, it being necessary to use this hard steel in order to prevent too rapid wear of the tongues, also too rapid wear at the point where the heads come together.

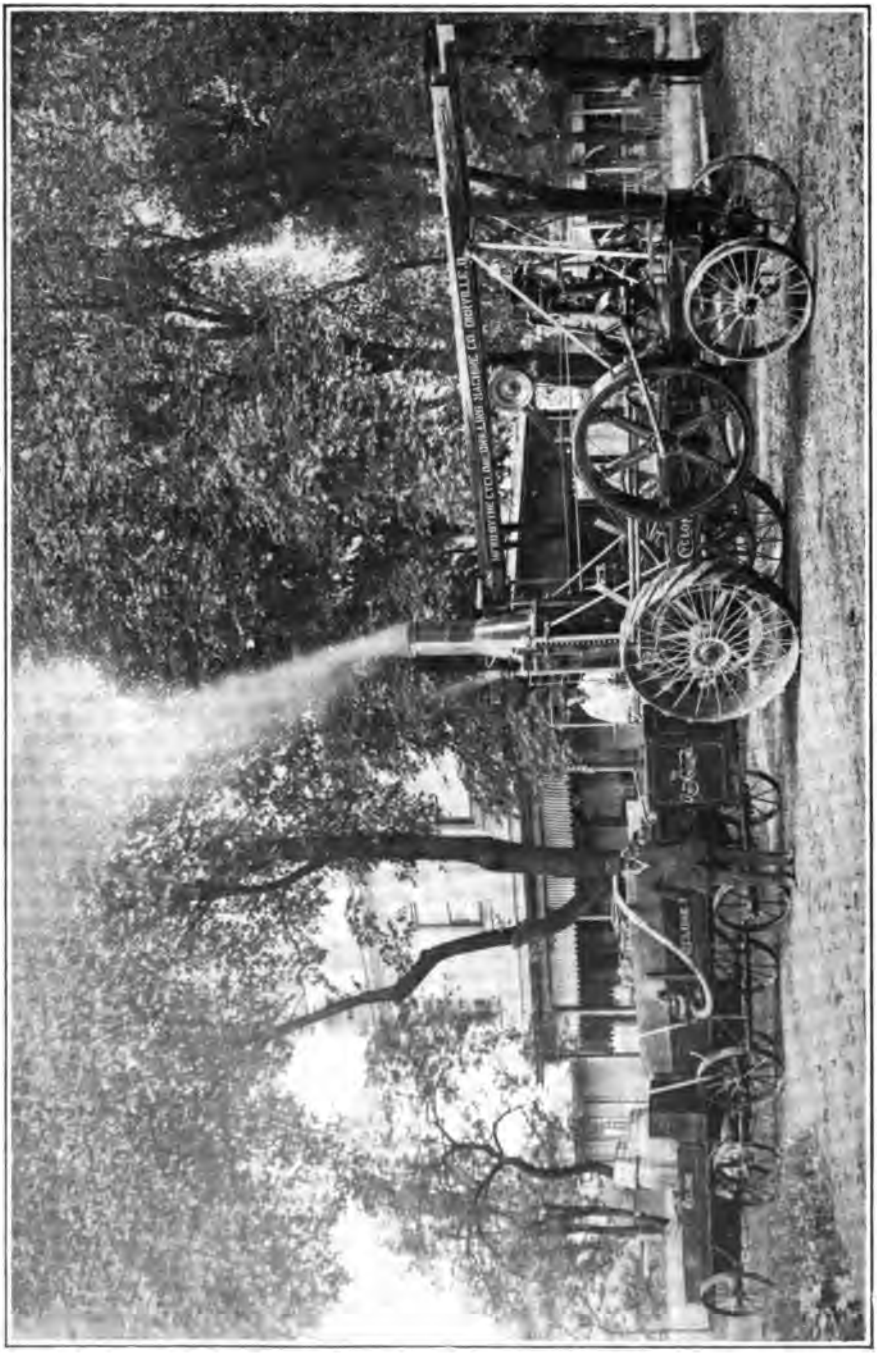
The instructions given on pages 51 and 52 in regard to taking care of jars should be followed out and when the heads become so worn that the metal is cut down within 2 or 3 inches of base of tongue the jars should be thrown aside or else used on but very light work.

The following table shows dimensions of jars to be used in holes of different diameters:

| Range in diameter of holes to be used in, Inches | Diameter of Jars Inches | Approximate Weight Pounds |
|---|---|---|
| 3 to 4 | 2⅝ | 70 |
| 3½ to 4½ | 3 | 80 |
| 4 to 5 | 3½ | 100 |
| 4¼ to 5⅝ | 3⅞ | 125 |
| 5 to 6 | 4¼ | 145 |
| 5⅝ to 7 | 4½ | 200 |
| 6 to 8 | 5 | 260 |
| 6¼ to 10 | 5¼ | 300 |
| 7⅝ to 12 | 6¼ | 450 |
| 8 to 12 | 6½ | 500 |
| 8¼ and larger | 7 | 600 |

In the above table the sizes given are for jars for water well drilling and not for oil well work. It is the usual custom to use jars of slightly smaller diameter for drilling water wells, owing to the fact that, in this work the holes often have a large amount of water and thus the tools must not fit the holes too close. In oil well drilling, the water is usually cased off, and, as long, heavy stems are used, jars of the very largest possible size are to be recommended.

You will note in the table of jars, that the measurements given are made with reference to range in diameter between two sizes of holes. The jar table is so arranged, owing to the fact that jars of a given size are often used in holes of different diameters. However, any particular size should not be used in holes smaller than the smallest hole given. Thus a set of jars having a diameter of 4¼ inches should not be used in a hole smaller than 5 inches nor in a hole larger than 6 inches.


MANUFACTURED BY THE CYCLONE DRILLING MACHINE CO. ORRVILLE, O.

Steam Traction type of Cable Drill with Complete Well Drilling Equipment.

## Drill Bits.

As stated under "Bit Dressing" the bit is the business end of the tool equipment, and demands proper attention and skill in handling.

Not only must judgment be exercised in dressing and tempering the bit, but what is of equal importance, the bit to start with must be of proper shape and size for handling the kind of work which it is expected to do.

Broadly speaking, there are two kinds of bits—Spudding bits and Rock bits.

A Spudding bit is for use in sand, clay, gravel, etc., and is made somewhat thinner than a regular rock bit owing to the fact that in drilling in material above bed rock the action of the bit is such that it simply stirs up the material, thus giving it a chance to mix with the water.

A thin spudding bit will make hole much more rapidly in the material above bed rock than a regular rock bit, as the rock bit is so blunt that it has a tendency to pack the material without mixing it.

Another trouble experienced in using a rock bit is, that it "muds" up very rapidly owing to the fact that it fills the hole so completely.

A Rock bit, as the name implies, is for use in rock drilling, and, inasmuch as it is necessary to dress a rock bit with full wearing surface and also, owing to the fact it is harder to keep a hole straight in rock than in dirt, it is necessary to make a rock bit much thicker than a spudding bit.

As stated under "Drilling in Rock" pages 52 to 62, several different types of rock bits are manufactured for use under varying conditions of rock drilling.

It is, however, possible to construct a standard type of rock bit which will cover pretty completely the entire rock drilling field and which may, by proper dressing, be made to successfully cover all classes of rock drilling, excepting those which are the most severe.

To construct a bit of proper proportion so that it will answer for a universal rock bit, it is necessary that the various dimensions be carefully considered. That is, the bit must be so proportioned that it will admit of being dressed for different classes of rock drilling and yet will be of such shape that it is a safe bit to use in the various classes of formations.

By referring to table given on page 103 you will note the various measurements and specifications which are considered in the construction of a bit. These are as follows:

**Size of Bit.** By this is meant the size of hole the bit is to be used in, or in other words the size the bit will be when dressed for business.

**Size of Joint.** This dimension determines the size of pin and also the size of collar and wrench squares.

**Length of Bit.** This dimension is the distance from shoulder of joint to cutting edge.

**Amount Soft Steel.** This is the steel used on pin end of bit. As a rule the amount used does not vary in bits of the same size. Where it is desired to increase the length of bit it is usually done by increasing the amount of tool steel.

**Amount Tool Steel.** This is the steel used in cutting end of bit.

**Total Weight.** The weight can of course be determined by adding the weights of soft steel and tool steel.

**Width of Blade.**

**Thickness of Blade.**

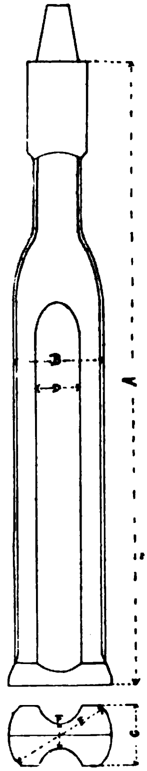
**Diameter Blade Across Corners.**

**Width of Water Channel.**

**Thickness in Water Channel.**

By referring to accompanying cut it will be understood how the various measurements are taken.

*A.* Gives total Length.
*B.* Width of Blade.
*C.* Thickness of Blade.
*D.* Width of Water Channel.
*E.* Diameter across corner of Blade.
*F.* Thickness in Water Channel.



The various dimensions given for bits of different sizes, in the table on page 103, are such as have been found best for bits which are to be used on portable water well machines.

On heavy oil well outfits the bits are usually longer, and are sometimes wider and thicker, but as already stated, very heavy stems are used in oil well work and thus bits which are of proper proportions for the heavy outfits are not adapted to water well equipments.

By referring to accompanying cut and also to table on page 103, it will be seen that there is a fairly constant ratio between the thickness of blade and the width of blade, this ratio ranging between 1 to 1.3 and 1 to 1.5. It will also be noted that the ratio between the width of blade and the diameter across corners is fairly constant, this being approximately 1 to 1.1.

The meaning of the above, stated in other words, is, that, as the width of blade increases, the thickness of blade and also the diameter across corners increase in a proportionate amount. It is neces-

## Dimensions Standard Rock Bits for Portable Drilling Machines.

| Size Bit, Inches | Size Joint Inches | Length Bit Approximately Inches | Amount Soft Steel Pounds | Amount Tool Steel Pounds | Total Weight Approximately Pounds | Width Blade Inches | Thickness Blade Inches | Diameter Blade across corners Inches | Width Water Channel Inches | Thickness in Water Channel Inches |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1⅛ x 1¾ | 36 | 40 | 30 | 70 | 2⅜ | 1¾ | 2 11/16 | 1¼ | ⅝ to ¾ |
| 3½ | 1⅜ x 2 | 36 | 55 | 40 | 95 | 2⅞ | 2⅛ | 3 3/16 | 1⅜ | ¾ to ⅞ |
| 4 | 1⅝ x 2½ | 42 | 64 | 40 | 104 | 3¼ | 2½ | 3⅝ | 1½ | ⅞ to 1 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ⅞ to 1 |
| 6⅝ | 2 x 3<br>up to<br>2½ x 3½ | 48 | 133 | 120 | 253 | 5¾ | 4¼ | 6⅜ | 2⅞ | 1½ to 1⅝ |
| 7⅝ | 2 x 3<br>up to<br>3 x 4 | 48 | 145 | 150 | 295 | 6¼ | 4½ | 7 | 3½ | 1½ to 1¾ |
| 8 | 2 x 3<br>up to<br>3¼ x 4¼ | 48 | 218 | 200 | 418 | 6½ | 4⅝ | 7¼ | 4 | 1¾ to 2 |
| 10 | 2½ x 3½<br>up to<br>4 x 5 | 48 | 306 | 300 | 606 | 8 | 6 | 9 | 4¾ | 2 to 2⅛ |
| 12 | 2½ x 3½<br>up to<br>4 x 5 | 48 | 400 | 350 | 750 | 10 | 6½ | 11 | 5 | 2⅛ to 2½ |

You will note that two sizes of bits are listed for 5, 5⅝ and 6 in. holes. The smaller bits of these sizes are given for the purpose of showing the sizes of bits which should be used on very light stems, and are not to be recommended for drilling in hard rock or formations.

---

# ERRATA

Bit table page 103, the "thickness of blade" of 6 inch bits should be 3⅝ instead of 3⅜ inches.

Bit table page 103, the next "size of bit" after the 6 inch bit should be 7 inches instead of 6⅝ inches.

Page 318, the page reference in line 7 should be 316 instead of 315.

Page 318, the page reference in third line from bottom should be 316 instead of 215.

sary that this be so or otherwise the bits of larger sizes would have so much play in the hole that it would be almost impossible to keep the hole straight. Thus a bit which is of proper thickness for a 6 in. hole is entirely too thin for an 8 in., 10 in. or larger hole.

The writer has often seen drillers stove up 5⅝ or 6 in. bits for use in 7 or 8 in. holes, claiming that the small bits were as satisfactory as bits of proper sizes. You will find, however, that drillers following the above practice will spend a good deal of their time reaming and straightening holes.

Another trouble experienced in using a thin bit for rock drilling is, that it is a hard matter to get the wearing surface as full as should be used and thus the hole is liable to become "flat."

The dangers outlined above are not so great where the drilling is "good" and thus it may be your experience to find in your section of the country drillers who employ the above methods with satisfactory results, but do not let this mislead you into following in their footsteps as it is taking chances and this is something which a drill man MUST avoid if he wants to establish a reputation as a successful well driller and expects to make the greatest possible profits out of the business.

To illustrate the importance of proper proportioning of bits, we will refer to dimensions of 8 in. bit in table page 103.

You will note that an 8 in. bit should have a blade 6½ in. wide, 4⅝ in. thick, and 7¼ in. across corners. Now as this bit is to be used in an 8 in. hole, there will be ¾ of an inch between each edge of blade and sides of hole and ⅜ of an inch between the corners of blade and sides of hole. Thus the bit does not have to be stoved over ¾ of an inch on a side in order to bring it to gauge and as the diameter of the blade across corners is 7¼ in., this leaves, as stated above, ⅜ in. between corners and sides of hole.

As the bit has four corners which extend upward in straight lines from the top of bit faces, to the taper at shank, these four corners will hold the bit straight in the hole and thus prevent the tools from "drifting."

Now suppose a 6 in. bit was used for drilling an 8 in. hole. By referring to table we find that a 6 in. bit has a blade 4⅞ in. wide with a thickness of 3⅝ in., while the diameter across corners is only 5½ in. Thus it would be necessary to stove the 6 in bit 1 9/16 in. on a side, while the space between corners and sides of hole would be 1¼ in., this space being so great that the tools would have an easy chance to "drift."

As we have explained the functions performed by the corners of blade, it will now be easily understood why oil well drillers prefer extra long bits, as the longer the bit, the greater is its ability to guide the tools, thus keeping the hole straight.

You will note in the above discussion that the writer refers to corners of blade of bit which must not be confused with corners of cutting end of bit referred to under "Bit Dressing," as the corner of blade is an entirely different part from corner of cutting end, as shown on page 75.

Now to return to the bit table. You will note that the 5, 5⅝ and 6 in. bits are made up with two sizes of blades. The smaller blades of these three sizes are for bits which are to be used with very light strings of tools, the stems of these light tools not exceeding 3 in. in diameter by 12 or 14 ft. in length.

Where easy drilling is encountered, the small bits are very satisfactory, but where hard drilling is encountered or difficult formations are met, heavier drilling tools equipped with the thicker bits should be used.

You will also note, that, beginning with the 5⅝ in. bits, different sizes of joints for the same size of bit are given. Thus, on bits for drilling a 5⅝ in. hole, joints either 2 x 3 or 2¼ x 3¼ can be used. Also the same size joints can be used on 6 in. bits, while as the bits become larger, larger joints must be used. Thus on 7 in. bits the joints can be 2 x 3, 2¼ x 3¼ or 2½ x 3½.

On 7⅝ in. bits the joints can be as large as 3 x 4, while on bits 10 in. or larger, the joints can be as large as 4 x 5.

The proper proportioning of joints to be used on drilling tools will be more thoroughly discussed later, under "Drilling Tool Joints."

By again referring to bit table, it will be noted that two kinds of steel are used, namely soft steel on pin end, and tool steel on cutting end.

Soft steel is used on pin end for the reason that this kind of steel can be much more readily cut with lathe tools, thus admitting of the making of the best possible threads and smoothest possible shoulders.

Another reason is that the soft steel does not crystallize so readily as tool steel and thus the pins are stronger, and the threads are not nearly so brittle.

There is now being placed on the market by some of the oil well-drill-tool manufacturers, bits made of all tool steel which are claimed to be as satisfactory as bits made of both soft and tool steel.

Where the bits are of such size that big pins can be used, that is pins 3 x 4 or larger, and where the drilling is not above medium hardness, the the all steel bits prove very satisfactory, but where the pins are smaller than 3 x 4, or where extremely hard drilling is encountered, the writer emphatically recommends the bits with the soft steel upper end.

The trouble with the all steel bit is that the steel in pin becomes crystallized by the constant hammering which it receives, thus becoming brittle, causing the pin to snap off, or else, what is almost as bad, causing the threads of pin to break off in box, so that when the bit is unscrewed the threads are stripped.

The manufacturers of the all steel bits claim that in annealing the pins in order to turn them, the crystallizing tendency is done away with, but this the writer has found by experience to be only partly true.

It will be found that the steel in an annealed pin even though annealed in a most careful manner, is not affected to any considerable depth, thus leaving the great body of the pin unannealed and in a brittle condition.

It will also be found that the thin layer of annealed steel will gradually return to its former hard state and when this occurs the threads are very liable to strip.

Another disadvantage of the all steel bit is that the threads of pin are harder than the threads in box of stem and thus the box threads are soon cut out, or else are so altered that a new pin cannot be used in the old box.

Another trouble shows up when it becomes necessary to fish for an all steel bit lost in the hole. This trouble is caused by difficulty experienced in making the slips of fishing tool take hold of the collar of bit, due to the hardness of the same. However, as it is generally possible to spud around a lost bit, thus loosening it up, this latter objection is not so serious.

While the all steel bit has the several objectionable features outlined above, it yet has two advantages, one of which recommends it to the manufacturer, the other of which recommends it to the drill contractor.

The advantage to the manufacturer is that the bit can be made cheaper owing to the fact that it is not necessary to make a weld.

The advantage to the drill man is that when the bit becomes too short to use, it can be forged down to a smaller size thus lengthening it out to proper length. Thus, if a 12 in. bit is being used and becomes too short for 12 in. work, it can be forged down to 9⅝ or 10 in. bit, and when it becomes too short for this size it can be drawn down to a 6 or 8 in. and so on.

However, as an all steel pin of a size smaller than 3 x 4 is a pretty dangerous proposition and as a 7⅝ in. hole is the smallest hole in which joints 3 x 4 can be used, the advantages to the drill man of all steel bits are to be found, if found at all, in bits larger than 7⅝ in.

As stated on page 101, all bits can be broadly classified under two heads, namely, Spudding Bits and Rock Bits.

The Spudding Bit is, as a type, always made in one general style, that is, it has a broad, thin blade.

On the other hand, Rock Bits are made up in several different types to meet varying conditions.

The table on 103 gives the dimensions of bits well proportioned for general rock drilling, but as shown on page 61 there are other patterns, namely, the Star Bit and Mother Hubbard Bits. Besides the last named, there is the Russian pattern, a bit somewhat similar to the regular spudding bit and one seldom used.

There is also the Flat Bit which is made up the same as a Standard Bit excepting that it is without water channels. This type of bit was at one time used quite extensively in obstinate formations, it being the opinion of drillers that it was less liable to drift in the creviced and shattered rock. It was also supposed to be easier to dress. However, these bits are now seldom used as they will not drill so rapidly as a fluted bit and are found to be of no special advantage.

Other bits of special shape will be discussed under "Fishing Tools and Tools for Special Conditions."

## Bailers.

Bailers for ordinary water well work are made up of three parts—the Bail, the Shell and the Valve.

**Bail.** The bail is usually made of a U shaped piece of round soft steel with ends flattened out and rounded, the rounded ends being made to correspond with the circumference of shell, so that they can be riveted to the same.

The flattened ends of bail should be slightly offset and should always be placed on inside of shell so that the exterior of bailer will present a perfectly smooth surface, as otherwise the bailer is liable to "hang up" on any bump in the pipe or in the hole, resulting in tearing the bail loose from the shell, or else parting the sand line.

On very large bailers it is sometimes the custom to use two bails placed at right angles to each other. When this is done, one bail is placed just above the other. The two bails are not only stronger than the single bail, but, being placed at right angles to each other, they have the added advantage of preventing the top of bailer from catching on the bottom of pipe, when drawing bailer from the hole.

Another method of overcoming this catching tendency, when only one bail is used, is to cut two V shaped openings in top of bailer shell, one on either side of the bail. The large part of V should be at top of shell and should be of such size that it reaches to both legs of bail. The length of V should be from 5 to 10 in., depending upon diameter of bailer.

**Shell.** As a rule, bailer shells are made up of either boiler-flue tubing or else of light casing. In figuring the size of a bailer, the diameter is measured on outside of shell, while the length is figured according to the length of piece of tubing or casing used.

**Valve.** As shown on page 16 two types of valves are used, the dart valve and the flat valve. For water well work in holes 4 in. or larger in diameter, the dart valve is to be preferred owing to the fact that it is self dumping.

The advantage of the flat valve is that it permits the largest possible opening in a bailer of given size, but, as in dumping it, it is necessary either to set it on a stake or else up-end it, it is somewhat unhandy.

By referring to cuts of valves, page 16, you will note that the piece which forms the valve seat is constructed with an outside shoulder at lower end. It is very necessary that this shoulder be there, as otherwise in dumping the bailer, or when it strikes upon the bottom of hole, the full force of the blow will fall upon the rivets, which hold the valve in place. In this regard the writer would advise that care should be exercised in the manner in which a dart valve bailer is dumped.

In dumping, do not let the end of bailer slam down against the ground, or what is worse still, against a piece of plank or big rock, as it will take but a few such blows to loosen the rivets and start a leak between the valve and shell. This leak will probably not show itself while bailing heavy sludge, but when the well is finished and it is desired to test the well by bailing, it will be found that the water escapes. This leak not only cuts down your bailing capacity, but it makes it very disagreeable on the man handling the bailer.

After a bailer has been in use some time, especially if used in sand rock, it will be found that the rivet heads have become worn very thin. When this occurs, replace the old rivets with new ones. If the bottom of shell has become expanded so that it does not make a close fit with valve, cut off about three inches of the shell. In cutting off use a hack saw or else cut off on a lathe. Never attempt to use a cold chisel in cutting off and never hammer the end of shell, as both of the above operations will expand the shell, making it impossible to prevent the bailer from leaking.

By again referring to page 16 you will note from cut of dart valve that a hole has been drilled through the "dart" near the lower end. This hole is placed there so that the bailer can be used for dumping water in a hole which is liable to cave.

In some holes, the material penetrated is of such caving nature that pouring water in from the top will cause the hole to cave badly. Where such is the case, the water can be lowered to bottom of hole in the bailer.

To do this, bolt a small rod or a piece of small pipe a few feet in length to dart of bailer so that when the bailer is within a few feet of the bottom the valve will be opened.

The bailer could of course be used without the rod, but in this case it would not be completely emptied.

When it is necessary to use bailer for lowering water, care must be exercised both in lowering bailer and withdrawing same, in order to prevent the motion of the bailer and bailer line from causing the same trouble it is used to prevent.

Also in running in and drawing out the drilling tools, extra care must be taken where caving material is encountered.

Some drillers lower water by using paper sacks, but this is a slow, tedious method and not to be recommended.

Besides the regular type of bailer described above and the vacuum type described on page 17, there are several special types, which though used extensively in oil well work, are seldom used in water well drilling.

Among these special types may be mentioned the double-end bailer which is provided with dart valves at both ends, this bailer being used for bailing wells having a strong gas pressure. In using the doubld-end bailer, the bailer line is fastened to the dart of top valve, thus preventing the water from being blown out by the gas.

Another type of bailer, is the sectional bailer which is made up of sections of pipe, connected together with either flush or coupling joints. These bailers are sometimes made up with four or five sections, having a total length of 80 to 100 feet, being used for quickly bailing out a well which makes considerable water.

There is also a type of well cleaning tool, which while it cannot be classified as a bailer, yet, owing to the fact that it is used for cleaning out a well, will be described here. This tool is known as a mud socket and is used on the bottom of a light stem or on a set of jars. This tool consists of a piece of heavy pipe or tubing welded on to a drilling joint and carrying, about one foot from the lower end, a flat valve.

In using the mud socket, the tools are churned up and down as in drilling, the mud and cuttings being forced up in the tube, which when full, is brought to the surface and dumped.

Sometimes the mud socket is equipped at its lower end with a thin bit, in which case it is known as a combination bit and mud socket. Neither of the above tools should be used for drilling, unless the material to be penetrated is very soft, as they are designed for cleaning-out work only.

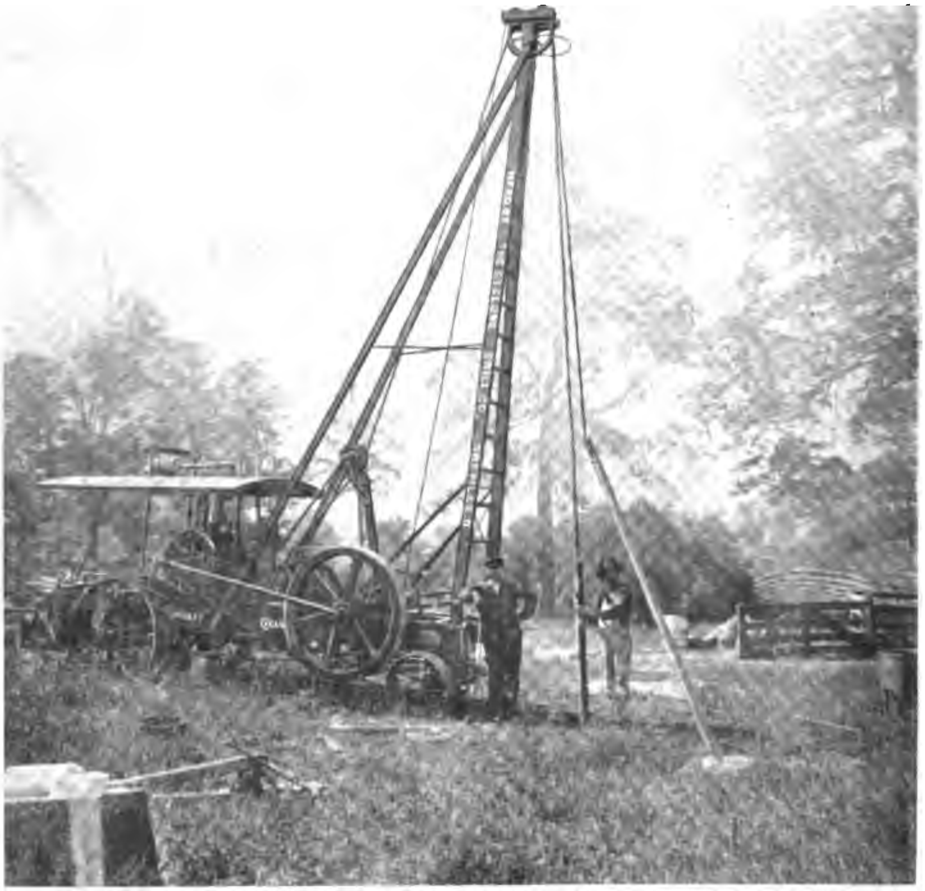
In figuring the proper size of a bailer to use, two factors must be taken into consideration, namely, the diameter of hole and depth of hole. In holes of shallow depths, it is the usual custom to use bailers not only of shorter lengths, but also of slightly smaller diameters than in the deep holes, so that the diameter of bailers is affected by the depth of holes as well as by the diameters of same.

The reason for this is, that in the deep holes quite a bit of time is consumed in "running" the bailer and thus, in order to save time, by making it necessary to run it as few times as possible, a bailer having the largest diameter, it is safe to use, should be employed.

It may occur to the reader to ask the question, why if it is possible to use a bailer of a given diameter in a deep hole, it is not possible to use the same diameter bailer in a shallow hole, of the same size.

The answer to this is that, as stated on page 93, the various parts of a drilling equipment must be in proportion.

On deep well machines provision is made for handling heavy bailers by making the sand reel and all parts connected thereto of sufficient size and strength so that a heavy sand line can be used; also the power used on heavy machines is ample for rapidly and satisfactorily handling heavy bailers.



Gasoline Traction type of Cable Drill.

On the other hand, on the small machines, in order to keep the parts in proportion and thus make them work to their best advantage, it is necessary that a compromise be struck, and the bailer brought down to a size commensurate with other parts of drilling outfit.

In the table which follows it will be noted that the variation in diameters between bailers used in shallow holes and those used in deep holes is not great, yet in practical field work it will be found that the variations, though slight, make a very noticeable change in the operation of an outfit.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outside Diam. Bailer..........Inches | 2½ | 3 | 3¼ | 3½ | 3¾ | 4 | 4½ |
| Weight of Bailer 10 ft. long...Pounds | 47 | 53 | 58 | 66 | 70 | 76 | 102 |
| Smallest hole to be used in up to 500′ | 3 | 4 | ... | 5 | ... | 5⅝ | 6 |
| Smallest hole to be used in above 500′ | 3 | 3½ | 4 | 4¼ | 4½ | 5 | 5⅝ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outside Diam. Bailer..........Inches | 4¾ | 5 | 5½ | 6 | 7 | 8 | 9 |
| Weight of Bailer 10 ft. long...Pounds | 108 | 114 | 144 | 176 | 227 | 272 | 335 |
| Smallest hole to be used in up to 500′ | 6⅝ | 8 | 8¼ | 10 | 12 | ... | ... |
| Smallest hole to be used in above 500′ | 6 | 6¼ | 6⅝ | 7⅝ | 8¼ | 10 | 12 |

You will note in the above table that the bailers are figured according to the smallest hole in which they are to be used, this being the method used in figuring all other drilling tools.

It is of course possible to use a bailer of any given size in a hole larger than that for which it is listed, the only objection to this being the slowness with which a small bailer will clean a large hole.

On the other hand do not attempt to use bailers in holes smaller than those for which they are recommended in the "greater-than-500 ft. list," as in this list the very largest possible bailers for the different sizes of holes are given.

In the less-than-500 ft. list the bailers are such as will be found well adapted for machines capable of drilling the different sized holes.

Thus a machine which is capable of swinging tools for drilling a 5⅝ in. hole should be able to handle a bailer 4 in. in diameter, while a machine capable of swinging tools for drilling a 10 in. hole should be able to handle a 6 in. bailer.

The length of bailer also enters largely into consideration, especially on the smaller machines where it is necessary to exercise extra care and judgment in order to provide the outfits with an equipment which will produce the greatest results without overloading or overtaxing the machine.

Some drillers seem to think that by overloading a machine with a tool outfit larger than it is designed to carry, they are thereby increasing their drilling rate. This is a very much mistaken idea, as a machine crowded to its limit, will not only handle the tools in a less satisfactory manner, thus cutting down the drilling speed, but, owing to more numerous delays due to breakdowns, the actual time of drilling is reduced.

The following table gives lengths of bailers well adapted for holes of different depths:

| Length of Bailer<br>Feet | Depth of Hole<br>Feet |
|---|---|
| 8 to 10 | 0 to 250 |
| 10 to 12 | 250 to 350 |
| 12 to 14 | 350 to 500 |
| 14 to 16 | 500 to 750 |
| 16 to 18 | 750 to 1,000 |
| 18 to 20 | 1,000 to 2,000 |
| 20 to 25 | 2,000 to 3,500 |

The above figures can be followed closely for bailers up to 7 in. in diameter, but where the bailers are 7 in. or larger, some drillers prefer to use bailers of shorter lengths than those given for holes above 1,000 ft. in depth.

Thus you will note that for drilling holes 1,000 to 2,000 ft. a bailer 18 to 20 ft. in length is recommended, but as a large diameter bailer, 18 to 20 ft. in length, becomes very heavy when filled, drillers often specify that the large bailer shall not exceed 16 ft. in length.

However, for bailers up to 7 in. the table can be accepted as standard.

What has been said above in regard to lengths of bailers refers to standard bailers for regular drill work and does not include sectional bailers, which as previously referred to, are used for a special purpose.

You will note in the first bailer table that the weight for bailers of different diameters are given, the weights being figured for bailers 10 ft. in length.

If it is desired to find out the weight of any given sized bailer of greater length, it can be done by adding on to the weight of the 10 ft. bailer the weight of the additional shell used. This weight can be found by referring to casing table page 36.

As bailers are listed according to their outside, and not inside diameters, the "Outside Diameter" column of table must be referred to.

Thus, to get the weight of a 3¾ in. bailer, we run down the column until we come to casing having an outside diameter of 3¾ in., which casing we find has an inside diameter of 3½ in. and weighs 4.6 pounds per foot.

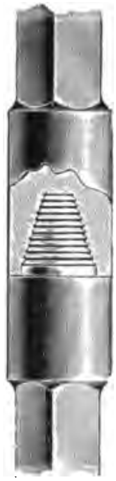
Now suppose it was desired to figure the weight of a 3¾ inch bailer 20 feet in length. The bailer table shows us that a 3¾ inch bailer 10 feet long weighs 70 pounds. We have found from casing table that a foot of 3¾ inch bailer shell weighs 4.6 pounds which for a 20 foot bailer makes 46 pounds above the 10 foot weight, or a total weight, for 20 foot bailer, of 116 pounds.

You will note in the casing table that casing of the same size is made up in different weights. In figuring bailer weights, take the lowest weight given, as casing of the lightest weight is always used for bailer purposes.

## Drilling Tool Joints.

In selecting a set of drilling tools the proper proportioning of joints to be used is perhaps as important as any other single item connected with the tool equipment.

As explained under "Auger Stems and Sinker Bars" also "Drill Bits," it is necessary that the sizes of joints used, be made to correspond in size with the tools on which they are to be used, but in this discussion we will go further and consider the correct proportioning of the various parts making up the joint proper.


Taper Joint.

In the early days of the drilling business, all joints were cut "straight," that is the pin had the same diameter for its full length. Now, however, it is the almost universal practice to use what is known as the taper joint.

This joint you will note from the accompanying cuts is made with the pin larger in diameter at the base than at top. This form of joint possesses much greater strength than the straight joint, owing to the fact that the base of pin, where the greatest strain occurs, can be made with the largest possible diameter and yet leave enough metal in the box, inasmuch as the sides of the box becomes heavier as the top of pin is approached.

The taper joint also has other advantages besides the matter of strength, among these advantages being the following:

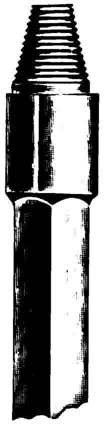
It can be more quickly connected and disconnected.

In case a thread strips, the joint can be unscrewed without stripping all of the threads.

When it is desired to re-thread a joint, whether pin or box, it can be done without entirely cutting off the old joint, it being necessary merely to cut back far enough to get below the base of threads.

The taper joint can be set up closer as the threads have a wedging action.

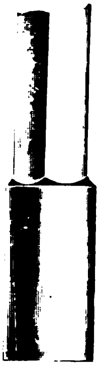
In making up a set of joints, there are several dimensions to be taken into consideration and it is only by a careful proportioning of these various dimensions that the best possible joint can be made.


Pin Joint.

It is, of course, possible to make a joint which will do, in a more or less satisfactory manner, without devoting careful study to its theoretical consideration or bestowing especial care in its construction, but such a joint belongs to the just-as-good class and it will generally give to the user the kind of service which all counterfeit articles give.

Owing to the fact that the making of good joints involves extremely close measurements and, as stated above, accurate and intelligent proportioning of parts, you cannot expect to buy good tools at "cheap" prices. The writer does not mean by this that is necessary for you to pay a fancy price for your string of tools, as there are now several reputable manufacturers who can furnish you tools at reasonable prices, but he wants to warn you against the habit of considering price rather than quality.

If, when buying a drilling outfit, the state of your finances is such that it is necessary for you to figure to the last penny, do your figuring on all parts of the outfit excepting those parts which are to be used in the hole, but on them do not take any chances, as a single fishing job, caused by defective tools, can easily cost you dozens of times the difference in price between a good string of tools and a just-as-good one.



Box Joint.

In making up a set of joints, the dimensions to be considered are:

Size of Joint.
Diameter of Pin Collar.
Diameter of Box Collar.
Length of Pin Collar.
Length of Box Collar.
Length of Pin.
Depth Box is Bored.
Number of Threads to Inch and Style of Threads.
Size of Square.
Length of Square.

The "size of joint" of course broadly describes the joint, as all the other dimensions should be made to conform to and be in proportion with the joints, as they vary in size. Thus when we say a joint is 2 x 3, we mean that the pin is two inches in diameter at top and 3 in. in diameter at base and that all other parts entering into the making of a 2 x 3 joint are in proportion.

However, as there are a large number of concerns making drilling tools and as all of these various concerns do not make joints with exactly the same proportions, it is a good plan for a driller to carefully study the joint problem so that he will be in a position to decide intelligently whether or not the joints on the tools which he is figuring on purchasing are correctly constructed.

As stated above, nearly all joints are made on a taper, and, as each drill tool manufacturer uses his own style of taper, it is very rarely that it is possible to get joints made by different manufacturers which will fit together, even though the "sizes of joints" are the same.

That is, a 2x3 joint made by one concern will not fit a 2x3 joint made by another concern. It is very unfortunate that such a condition exists, as it would make it much more convenient for the drill men if all manufacturers made joints exactly alike, but as there are now in use so many different styles of joints it would be impractical to attempt to standardize and make all joints the same.

In order to insure against badly fitting joints, all of your tools should be purchased from one manufacturer as any reliable manufacturer has templates for the different sizes of joints which he sells and thus it is possible for him to make all joints of each particular kind, of exactly the same size.

If, however, it is not convenient for you to purchase the additional tools from the same manufacturer from whom you purchased your first tools, then you should have the manufacturer who sold the tools, furnish you with templates of the joints, which templates will enable the second manufacturer to make an absolutely accurate fit.

While the templates will cost quite a bit, the price ranging from $10.00 to $20.00, depending upon size of joint, they will prove a profitable investment in the long run.

Of course, if all of your tools can be purchased from the same manufacturer, the templates will not be needed, as each manufacturer keeps a close record of all tools which he sells and is thus able to replace them with exact duplicates.

By referring to table on page 116 you will note that the diameters of box collars are slightly greater than the diameters of pin collars, for the joints of different sizes.

The collars are thus constructed not only for the purpose of making the box stronger, but also for the purpose of preventing the edge of shoulder of pin from becoming burred.

When the pin collar is the same diameter as the box collar, the dragging of the tools inside of the drive pipe and against the hard rock walls, will cause the edges of shoulders to slightly burr. Unless this burr is carefully removed each time the joints are set, it is very liable to cause trouble, owing to the fact that the burred edge will come against the shoulder of box, an action which will not only scratch and cut the box shoulder but will also prevent the pin and box shoulders from being drawn flat against each other so that the joint is very liable to become unscrewed in the hole.

It is the usual custom to bevel the edge of box collar so that the edge of bevel comes even with the edge of pin collar. In making this bevel a tool with a rounding cutting edge is used so that the cut or bevel is concave, that is, it is in the shape of what carpenters call an "o g" cut.

It is also the custom to slightly bevel the edge of pin collar. This bevel on pin collar, except for the large joints, should be slight, all that is needed being the edge a little rounded to prevent the occurrence of a "wire edge" which when present is liable to roll up.

Again referring to table you will note that the length of box collar is greater than the length of pin collar. A joint is so constructed for the reason that a box is bored about 1 in. deeper than the pin is long and thus the box collar must be somewhat longer than the pin collar in order to prevent the joint from being weakened at base of box collar, in case it becomes necessary to re-cut an entirely new box.

The lengths of collars given in the table are for drilling tools proper and do not apply to fishing tools and tools for special conditions. While such tools as spears, spuds, reamers, swedges and fishing tools of similar nature should have pin collars of approximately the same lengths as those given in table, still such tools as combination sockets, slip sockets, etc., are usually made with the collars somewhat shorter than shown in table.

| Size of Joint, Inches | Diameter of Pin Collar, Inches | Diameter of Box Collar, Inches | Length of Pin Collar, Inches | Length of Box Collar, Inches | Length of Pin, Inches | Depth Box is Bored, Inches | Number of Threads to Inch and Style of Thread | Size of Square, Inches | Length of Square, Inches | Smallest hole to be used in, Inches |
|---|---|---|---|---|---|---|---|---|---|---|
| 1⅛ x 1¾ | 2⅜ | 2 7/16 | 4½ | 6 | 2⅜ | 3⅛ | 8 Sharp | 1¾ | 2½ | 3 |
| 1⅜ x 2 | 2 13/16 | 2⅞ | 5 | 6½ | 2⅞ | 3⅝ | 8 Sharp | 2¼ | 3 | 3½ |
| 1⅝ x 2½ | 3¼ | 3⅜ | 5½ | 7 | 3⅜ | 4⅛ | 8 Sharp | 2½ | 4 | 4 |
| 1⅝ x 2½ | 3½ | 3⅝ | 5½ | 7 | 3⅜ | 4⅛ | 8 Sharp | 2½ | 4 | 4½ |
| 2 x 3 | 4⅛ | 4¼ | 6 | 8 | 4 | 5 | 8 Sharp | 3¼ | 5 | 5 |
| 2 x 3 | 4¼ | 4⅜ | 6 | 8 | 4 | 5 | 8 Sharp | 3¼ | 5 | 5⅝ |
| 2¼ x 3¼ | 4½ | 4¾ | 7 | 9 | 4 | 5 | 8 Sharp | 3½ | 5¼ | 5⅝ |
| 2½ x 3½ | 5 | 5¼ | 7 | 9 | 4¼ | 5¼ | 7 Flat | 4 | 5½ | 6¼ |
| 2¾ x 3¾ | 5¼ | 5½ | 7 | 9 | 4½ | 5½ | 7 Flat | 4 | 5½ | 6⅝ |
| 3 x 4 | 6 | 6¼ | 8 | 10 | 5 | 6 | 7 Flat | 4½ | 5¾ | 7⅝ |
| 3¼ x 4¼ | 6¼ | 6½ | 9 | 11 | 5 | 6 | 7 Flat | 5 | 6½ | 8 |
| 3½ x 4½ | 6⅜ | 6⅝ | 10 | 12 | 5½ | 6½ | 7 Flat | 5½ | 7 | 8 |
| 4 x 5 | 7 | 7⅜ | 10 | 12 | 5½ | 6½ | 7 Flat | 5½ | 7 | 9⅝ |

You will note from table the depths of boxes of different sizes, the extra length of box over pin being provided, in order to furnish ample space above the pin in case it is desired to leave the "center" on end of pin, and also in order to make it easier in the cleaning of the box.

By again referring to table you will note that the lengths of pins of different sizes are given. These dimensions are given merely for the purpose of making it possible for you to note the ratio which should exist between the length of a pin of any given size and the balance of the parts making up the joint. In actual practice it will be found that the lengths of pins vary somewhat from the figures given, the variation, however, as a rule, not amounting to over an eighth of an inch one way or the other.

When drillers first began using taper joints, the manufacturers attempted to make the joints according to tables. That is, the pin was cut a certain length, then turned to a certain diameter at base, then tapered off to a certain diameter at end.

It was supposed by these first manufacturers, and the supposition seems reasonable, that by having a table showing the length and the two diameters of all different sizes of pins, it would be possible to make joints which would be exact duplicates. It has been found, however, that the above method cannot be relied upon, the reason of this being that in order to produce a satisfactorily fitting joint, the measurements must be made with a degree of accuracy almost impossible to reach by relying upon measurements taken as above.

The present practice in turning a pin or box is to rely upon three dimensions, namely, the diameter at base of pin, the degree of taper, and the length of pin. The first two—the diameter at base, and the degree of taper are the main dimensions and must be absolutely correct. The length of pin can, however, have a comparatively wide range, it being possible for it to be as much as an eighth of an inch over-length or one-quarter or even one-half of an inch under-length, without seriously affecting the strength or fit of joint.

By degree of taper of a joint is meant the angle which a line drawn parallel with the outer edge of pin, would make with a line drawn perpendicular to the pin shoulder or what would amount to the same thing, the angle between a line drawn parallel with the outer edge of pin and a line drawn through center of pin.

In expressing the degree of taper, two methods are employed, one being to state it as the number of degrees and minutes of the angle, the other being to state it as the number of inches of taper per foot of length.

Some manufacturers prefer one method and some prefer the other, and while the writer believes confusion would be avoided by having all use the same standard of measurement, still, if the manufacturer will explain which method he uses there is not much excuse for error.

In order to turn a pin or box accurately, it is absolutely necessary that the lathe, on which the work is done, be fitted with a taper attachment and thus the turning of a joint should never be entrusted to ordinary machine shops which are not fitted for the business.

In fact, the turning of a good joint is such a particular piece of work that it is not good policy to allow any but experienced joint turners to handle the job unless you are so situated that the sending of the joint to be turned to the factory will involve a costly delay. Under such circumstances you would probably be justified in taking a chance, but the writer would impress upon you that it *is* taking a chance.

By again referring to joint table, it will be noted that the number and style of thread varies on joints of different sizes. On joints of a size up to and including 2¼ x 3¼ the threads are usually cut 8 to the inch and are what are known as "sharp" or "V" threads. On joints larger than 2¼ x 3¼ the threads should run 7 to the inch and should be made "flat." That is, instead of the thread coming to a sharp edge, as in the "sharp" or "V" thread, the top and bottom of threads are cut flat.

From the cut shown on page 113 you will note that the threads do not come clear to base of pin, the pin being cut straight for a distance of from ¼ to ⅝ inch, depending upon size of joint, up from the shoulder. This form of construtcion is used in order to prevent weakening of the pin.

Where the pin is tapered full length and the threads begin right at shoulder, the pin is much weakened, owing to the fact that the cutting of the bottom threads notches the pin at the point where the greatest strain occurs, thus making it easy for a break to start.

In setting up a joint it will be found that sometimes a small amount of metal dust or other foreign matter will be forced from between the male and female threads, out onto the pin shoulder, just at base of pin. If this foreign matter is allowed to remain and the joint set up, it may cause trouble owing to the fact that it will interpose a film between the two joint shoulders, which film will have a tendency to cause the joint to loosen.

In order to take care of the small amount of foreign matter mentioned above, it is now the usual practice to cut a "settling groove" at base of pin. This groove will of course vary in size on joints of different sizes, but as an average it should be about 1/32 to 1/16 deep and about ⅛ to 3/16 wide. By placing the grove just at base of pin, it will provide space to take care of the small amount of dirt squeezed from between the box and pin, thus preventing the dirt from being forced out onto the pin shoulder where it is liable to prove harmful.

In cutting the groove care must be exercised to see that it is cut on a radius, for should it be cut straight down to base of pin the strength of pin will be considerably decreased, for the reason that a square cut or an acutely angular one will provide a chance for a break to start.

By turning again to the table, you will note that the size of square and also the length of square, for joints of different sizes, are given. The dimensions shown are what have been proven best by experience and it will be found that all reputable drilling-tool manufacturers use approximately the same dimensions.

You will note that as the joints become larger, the squares are made both larger and longer. This is necessary on account of the fact that the larger the joint the greater the power required to set it up and thus the squares must be of such size that they will stand the strain thrown upon them and of such length that they will accomodate wrenches of proper size.

In making tool wrenches they are usually made from 3/16 to ¼ of an inch larger than the squares and their width should be in proportion to the size of square over which they are used, for should the wrenches be too narrow, the edges of squares will crumple and become rounded under the heavy strain thrown upon them.

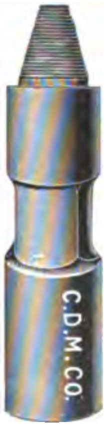
It will be found that the lengths of squares for joints of different sizes are somewhat greater than the widths of wrenches used. This extra length of square is provided so that the wrenches will not cramp on the square.

You will note from the cuts on page 15 that in setting up joints, one of the wrenches goes over the square at an angle and thus the square must be quite a little longer than the width of wrench or otherwise the wrench will bind.

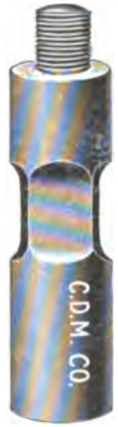
The squares can of course be made longer than shown in table, especially the squares on stems and bits, without interfering with their proper performance, but in case there is any variation from the the figures given, the variation should be above and not below the standard.

In making the pin square on drilling jars some manufacturers make simply a half square, that is, instead of making four sides to the square the square is just flattened on two sides. This is bad practice as it often makes it very inconvenient in setting the rope socket onto the jars, owing to the fact that some types of rope sockets are not provided with four-sided squares. Thus, when purchasing jars you should specify that the squares, especially the top one, should be four-sided.

You will note in last column of joint table, the smallest holes in which the joints of different sizes should be used. There are two main reasons for limiting the size of joints. First:—When joints are too large the collars will be of such size that they will drag in the hole, and, Second:—When the joints are of such size that the collars fill the hole too closely it makes it a hard matter to recover lost tools, owing to the fact that there is not sufficient space around them to properly operate the fishing tools.



Substitute for connecting Drilling tools.

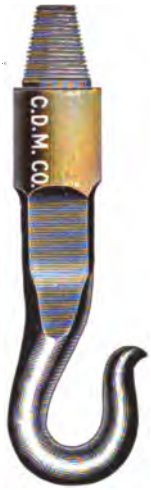


Substitute for connecting Pipe to Drilling tools

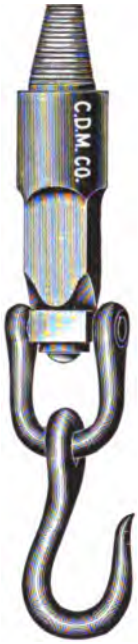
As has already been stated, there are many different styles and sizes of joints now in use, and, as drillers often desire to use a tool having one kind of joint on a string of tools having joints of different kind, the drill-tool manufacturers make a tool or part known as a substitute which consists of a pin of one kind or size welded onto a box of another kind or size.

Substitutes, as a rule are about 2½ to 4 feet long, depending upon size of joints and are made either for connecting together joints of different sizes or for connecting standard pipe to drilling tools. Pins and boxes are also made up with hooks and with eyes, these special forms of joints being used in connection with different parts of regular tool equipment for handling casing, drive pipe and other special work.

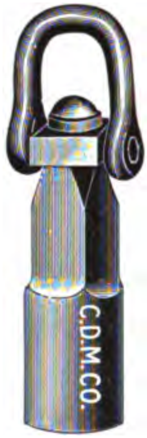
**Solid Hook with Pin.**



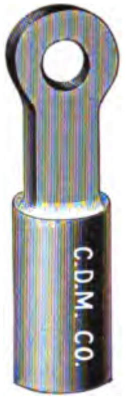
**Swivel Hook with Pin.**



**Box with Swivel.**



**Box with Eye.**



Before leaving the subject of Drilling Tool Joints, it will be well to add some further information regarding "Templates," referred to on page 115.

Complete box and pin templates consist of a pin, a box and a finger gauge. The pin of template is made the same length as pin on drilling tools, but the box of template is made from one-half to three-quarters of an inch shorter than the pin. The box is made shorter in order to make it more convenient in facing off the shoulder of pin which is being turned, and on which the box is being fitted. The finger gauge is of such width that the length of box plus the width of gauge just equals the length of pin.

As already stated each manufacturer has particular kinds and sizes of joints, which he uses on tools of different sizes and thus, in order to avoid confusion, each template which he furnishes is marked with such dimensions as will define it. Not only are dimensions given, but it is also marked with the manufacturer's name or initials, so that in case of doubt he can be communicated with. Thus a template should be marked :

2 x 3
8°-18′
8-Sharp
Cyclone

the meaning of the above being that the joint is 2 x 3, on a taper of 8°, 18′, with 8 sharp threads to the inch and made by the Cyclone Drill Co.

# PART IV.

## Fishing Tools and Tools for Special Conditions.

It is impossible for a driller to anticipate all of the conditions which will be met in the drilling of a hole. It is also impossible for him to always detect the beginning of a break in drilling tools.

While good head work and close attention to details will reduce in a wonderful degree the chances for trouble, still, until that happy day arrives, when a man's foresight equals his hindsight, trouble in greater or less amounts can be looked for and thus it is well to be prepared beforehand for meeting it.

It is not meant, "by being prepared," that the driller should be provided with all kinds of fishing tools, but that he should be familiar with the different tools used for handling trouble of various kinds, so that he will know just how to go about the work.

Not only is it necessary that he know *what* to do, but he should also know what *not* to do, as it has been the writer's experience that many fishing jobs, which in the beginning were quite simple, have been very greatly complicated by lack of intelligent handling at the start.

In order that a driller can go about a fishing job intelligently, it is necessary for him to know the measurements of the various parts making up his drill-tool equipment, or as drillers would say his "string of tools." Thus, to be always on the safe side, a driller should carefully measure his string of tools as soon as he receives the same from the manufacturer and should jot down these various dimensions so that they will always be available.

Do not put off the securing of this information expecting to get it "sometime" as this "sometime" will probably find you with your tools "down in the hole" and you "up in the air."

The following dimensions should be secured :

Length of Rope Socket.
Outside Diameter of Top of Rope Socket.
Diameter of Hole in Top of Socket.
Diameter of Jars.
Length of Jars when closed.
Length of Stroke of Jars.
Diameter of Stem.
Length of Stem.
Length of Bit.
Width of Bit Blade.
Thickness of Bit Blade.
Size of Joints used on Tools.

Diameter of Pin Collar.
Diameter of Box Collar.
Length of Bailer.
Outside Diameter of Bailer.

While it is almost impossible to specify each and every kind of a fishing job that can arise, nevertheless, nearly all fishing jobs that have to do with the drilling tools proper, can be covered by the following classifications:

Cable Breaks, or as drillers say, "Cable Parts."
Rope Pulls Out of Socket.
Joint Came Unscrewed.
Jars Break.
Stem Breaks.
Bit Breaks.
Something Falls in on Top of Tools locking the Jars.
Something Falls in Hole, fastening the Tools below Jars.
Tools become stuck in bottom of hole.
Tools become stuck in pipe.
Gravel runs in hole under Drive Pipe.
Top of bed rock spalls off.
Bailer becomes lost in hole.
Something falls in on top of Bailer.
Valve pulls out of Bailer.

Besides the above troubles, a drill man is sometimes called upon to handle other unusual conditions, among the most common of these being the following:

Taking kinks and crooks out of pipe.
Recovering pump pipe lost in hole.
Straightening a hole.
Reaming a hole.

Other special work to be met with is:

Pulling drive pipe.
Re-casing a hole.
Pulling casing.

Before beginning the individual instructions for each particular class of fishing job referred to in the foregoing table, the following instructions, covering fishing jobs in general, should be considered:

Never experiment in the hole; if any experimenting has to be done, do it on top of the ground.

Never run a tool in the hole unless you are convinced that it is the proper tool to use.

Do not get excited, as fishing jobs require the exercise of a driller's best judgment.

In running a fishing tool always use a set of jars above the tool. When the lost tools are so fastened that hard driving will be required to loosen them, use a stem or sinker bar *above* the jars and if extra hard driving will be required, use a set of long-stroke jars which are made especially for fishing jobs.

The advantage of the long-stroke jars lies in the fact that a much heavier blow can be delivered, inasmuch as the full swing of the tools can be utilized.

Another advantage and a very important one is, that with the long stroke it is possible to get an up-jar without getting a down-jar. That is, the stroke of the long-stroke jars is of sufficient length to allow a full swing of the tools without the jars hitting on the down stroke.

This is not of such great importance when a light stem is used above the jars but when you are driving with a heavy stem it is very necessary to prevent the jars from hitting on the down stroke, as the down-jar will almost invariably loosen the slips besides being very liable to break them.

Fishing or long-stroke jars are made with lengths of stroke ranging from 8 to 24 in. for the small sizes, up to 36 in., for the largest sizes.

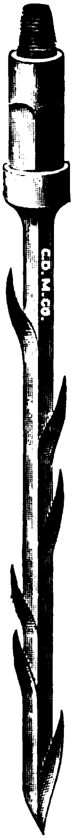
## Cable Breaks.

When a cable parts in the hole there are, broadly speaking, two courses to pursue, the course to be recommended depending upon whether the tools were working freely when the break occurred, or whether they were fast in the hole.

If the tools were working freely and you are sure that the break was not occasioned by something falling in on tools or the tools becoming fast in the bottom of hole, then the proper tool to use is a Rope Spear.

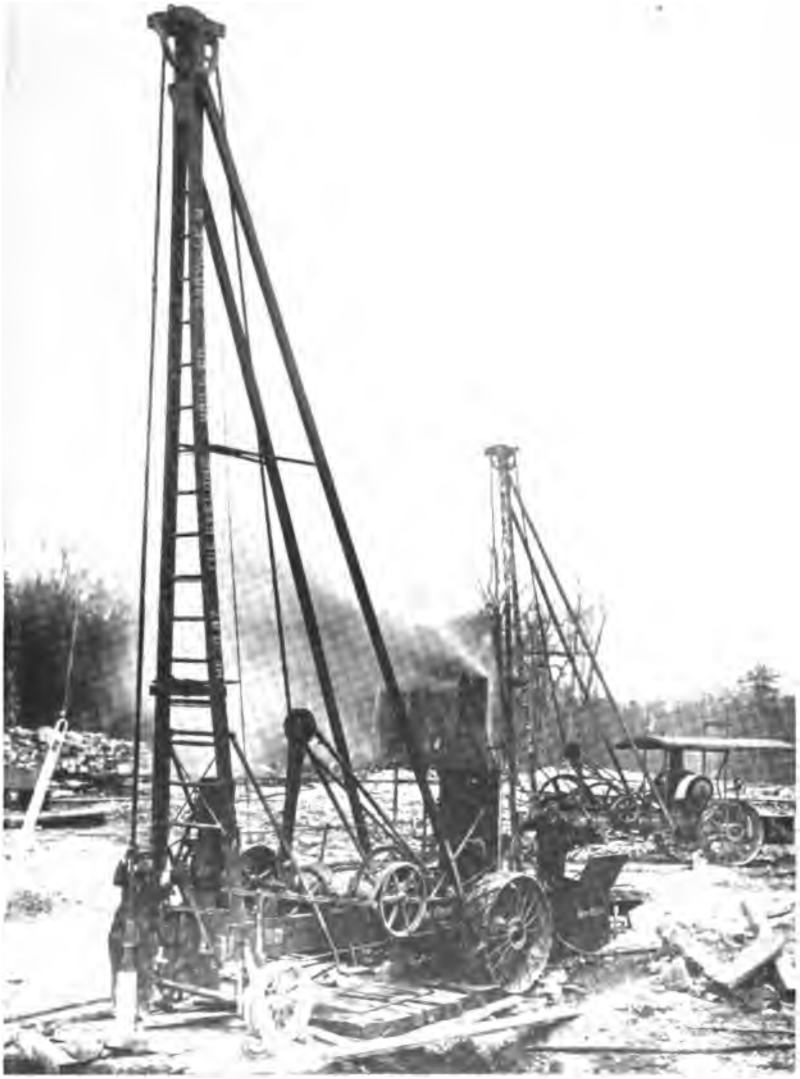
The only tools needed for this kind of job are rope socket, set of jars and rope spear. Some drillers do not even use the jars, using only the rope socket and spear, but this the writer does not recommend, especially if the tools lost in the hole are not provided with jars.

To use rope spear, screw it onto bottom of jars and lower it carefully into hole, allowing the spear to force its way down through the rope which will be curled up in hole.



Rope Spear.

If the spear is used in a hole having a diameter 1 in. or more, greater than diameter of joint collar on spear, rope should be wrapped around square of spear until the outside diameter of wrapped rope comes within about 1 in. of diameter of hole.



Two types of Traction machines, a Steam Traction and a Gasoline Traction at work drilling blast holes in stone quarry.

For this purpose a rope from 1⅛ in., to 1½ in. in diameter should be used, it being fastened by nailing the layers together.

The reason for wrapping the spear is to provide a collar which will force the parted cable ahead of top of spear, thus crowding the cable around the spear prongs so as to give them a chance to take hold.

After the spear has been forced far enough to insure that the parted cable is well tangled around the spear prongs, hoist the tools very slowly until the tension on the hoisting cable shows that the spear has taken firm hold, when the tools can be hoisted out of hole.

If the hole exceeds 500 or 600 feet in depth, it is a pretty good plan to fill it with water for a distance of 100 feet so that in case the tools break loose while hoisting them, the water will serve as a cushion, thus preventing them from striking the bottom of hole with destructive force.

In this respect we might add that on all fishing jobs, in holes deeper than 500 or 600 feet, it is well to take the precaution of pouring water in the hole, as it sometimes happens that the hold of fishing tools gives away allowing the tools to fall to bottom, and thus causing a much meaner fishing job than the one started with.

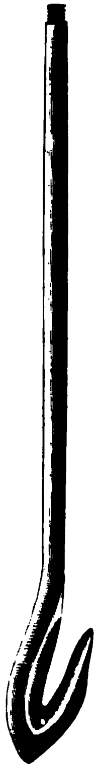
The amount of water to be used varies from 100 to 300 feet, but even on the very deepest holes do not use over 300 to 350 feet as the cushioning effect seems to be due to tools striking the water, which momentarily slows them up, after which they again pick up momentum almost as rapidly as if the water was not present.

In using water do not pour it in the hole until after the tools have been started up, as the presence of water around a set of tools adds to the difficulty of a fishing job.

Now to return to the fishing job.

If the parting of the cable has been caused by the tools sticking in the hole and you are not sure whether or not the jars on lost tools will work, or if the sticking of the tools is due to something falling in hole locking the jars, then the rope spear is not the tool to use, as it will be necessary to take hold of the lost tools so that they can be jarred loose.

As a rope spear works by catching the cable, thus leaving a greater or less length of the cable between the spear and rope socket of lost tools, the only strain which can be brought upon the lost tools is a direct pull and as this is not very effective, you stand a chance of leaving not only the drilling tools in the hole, but the fishing tools as well.



Rope Knife.

The first step to take is to get rid of the cable in the hole.

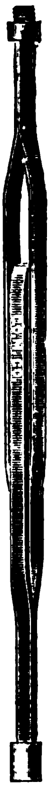
This can be done by use of the hook-rope knife and the rope chopper.

The rope knife should be used first as it is best to remove as much rope as possible before the rope chopper is called into play.

There are two ways in which the knife can be operated, one being to operate it on the end of a line of pipe or sucker rods, the other being to operate it on the end of sand line.

If the hole is not of great depth, the pipe will prove more satisfactory as your control of the tools is much better.

When pipe is to be used, attach the rope knife to the sucker-rod jars and then screw the pipe on above the jars. Lower the knife into the hole until it comes in contact with the parted cable, then twist the pipe until the hook on knife catches. Now raise the tools so as to see whether or not the hook has taken firm hold and if so, take a pull on the pipe until the rope is cut in two.



Sucker Rod Jars.

It may be that the rope cannot be cut by a straight pull, and if such is the case, it will be necessary to operate the jars.

This can be done by using the spudder on the machine, it being necessary, however, to set the spudder on the shortest stroke.

In most cases, where the parted cable is not above 1⅝ in. in diameter, and where the hook of knife is kept properly sharpened, a straight pull will generally do the business. The pull can be most easily applied by using the power of the machine, but care must be exercised to see that too great a strain is not applied as the hold of hook will be torn loose, the hook simply scraping along the rope without cutting it.

After a section of the rope has been cut loose, the tools should be pulled from the hole and the piece of cut rope removed.

Generally this piece will come up with the knife, but if not, it should be fished for until recovered, for should the rope be left, to be brought up with the next piece cut off, it may result in trouble as an attempt to remove a large amount of rope at one time may result in plugging the hole.

For this reason it is best not to push the knife too far into the rope at a time, as a piece of rope may be cut loose of such length that it will be troublesome to remove.

Continue cutting pieces from the rope and removing same until the rope becomes so short that the knife will not take hold, when the chopper should be used.

In case the rope knife is used on sand line, the tools to use are rope knife, sucker-rod jars and sinker rod, the knife being screwed to bottom of jars and the sinker rod on top of jars, the sand line then being fastened through eye at top of rod.

The sinker rod is added to give weight enough to force the knife through the tangled rope, also for the purpose of providing sufficient weight above the jars in case it is necessary to drive up with them.

As the handling of the knife on the sand line involves practically the same operations as with the pipe, its use will not be further discussed.

As it is hardly ever possible with a hook rope knife to cut the rope off smooth at the top of rope socket and as it is necessary to have the top of socket clean in order to use a fishing socket on top of it, some tool must now be used which will remove the small amount of rope left in hole.

If the hole is a shallow one, not over 200 or 300 feet in depth and not over 6 inches in diameter, a home-made tool can be used which will answer for this purpose very well. This tool can be used on the bottom of a line of ¾ inch pipe and should be made in the form of a short, sharp bit with the cutting edge about 2½ to 3 inches long.

The total length of bit should not be over 6 inches as a longer bit is liable to snap off in the hole.

In making the bit, use good grade of wrought iron, bending over, stoving up, and welding the upper end to proper shape and size so that it can be threaded to fit a standard ¾ in. coupling.

A piece of steel welded on the lower end will make a somewhat better cutting edge than the wrought iron alone, but unless the blacksmith making the weld is competent to do a good job, it is better to leave off the steel, as a piece poorly welded is liable to come off in the hole. Never make a bit of all steel as this is liable to snap off just below the coupling.

In operating the tool it should be lowered until it touches top of rope socket, and then carefully churned up and down until the rope has been cut away, so that top of socket is clean. In cutting, use short strokes and do not allow the tool to strike top of socket with much force, as this will cut the socket and may result in spreading it so that the fishing socket will not pass over it readily.

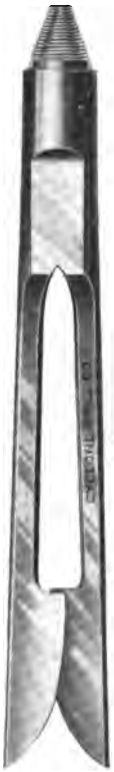
After the rope has been severed, the pipe tools should be removed and the remaining rope pulled from the hole, either with a hook made for the purpose or with a regular rope spear.

Sinker Rod.

If the hole is of such size or depth that the pipe tools cannot be easily and safely handled, then it will be necessary to use a rope chopper.

This tool is worked on the bottom of a set of drill jars, the chopping action being obtained by churning the tools up and down. You will note from the cut, the construction of the tool.

As the rope chopper chops the rope into fragments, it is necessary to clean the hole frequently. For cleaning purposes, a small spear having several wings proves very satisfactory. If it is not possible to have this kind of spear, the hole can be cleaned by the use of an ordinary bailer.



Rope Chopper.

A bailer having a flat valve will prove more satisfactory than one with a dart valve. In fact, a tool called a "Mouse Trap," which is simply a heavy bailer, screwed onto a drilling joint, the bailer having screwed onto its lower end a circular steel cutting edge carrying a flat valve, is often used, not only for bailing out chopped-up rope, but also for cutting it up as well.

To fill the bailer as full as possible, it is necessary that it be pumped as explained on page 57, and it is also necessary that the hole be filled with water up above the point where the chopping is being done.

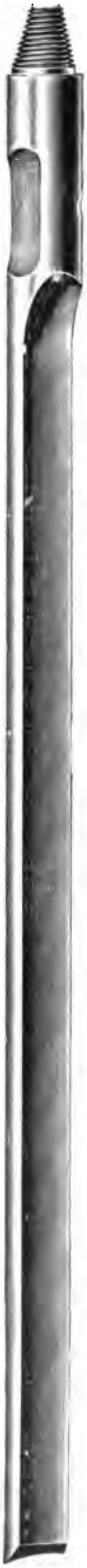
In dumping the bailer it will be necessary to force the rope out of top by pushing a rod up through from the bottom.

After having chopped up the rope and removed all of the rope fragments and cuttings down to top of rope socket, owing to the fact that the chopping and bailing operations will have forced quite a quantity of the rope cuttings down around the top of rope socket, it will be necessary to remove part of these cuttings in order to provide space for the fishing socket to slip down over top of rope socket.

On shallow holes this can be done by using a home-made tool on the bottom of a line of ¾ inch pipe. This tool should be made something on the order of the spud shown on page 129. For holes up to 6 inches in diameter, the blade of home-made spud should be made of good grade bar iron, ½ inch thick by 3 inches wide. For holes larger than 6 inches the blade should be thicker and wider, but where the spud is made larger it will be necessary to use it on the bottom of pipe larger than the ¾ inch pipe recommended above.

In using the spud it should be lowered until it strikes top of rope socket, then slowly churned up and down and moved around until it begins to pass down around the socket. As the spud goes down move it around, so that the socket is cleaned on all sides.

In running spud use shortest stroke and run slowly so that the spud will not become jammed between the tools and side of hole. If it is possible to do so, run the spud until the cuttings have been cleaned out down



Spud.

below the middle of jars, so that the jars will work when the tools are finally caught by the fishing tool.

You will be able to tell how far it is possible to run the spud by figuring the thickness of spud and the space between joints on tools and side of hole. It may be that the tools have become pushed over to one side, thus crowding them up against the wall, and where this is the case, it will be necessary to clean out around the open side first, after which, the spud can be driven down on the other side, thus forcing the tools over to center and affording a space for using the spud on the opposite side.

As the blade of a home-made spud should not be over 3½ to 4 feet long, it will not be possible to reach much past the center of jars, but this is sufficient, if the only material surrounding the tools is rope choppings and light cuttings. If there is anything else holding the tools, it will be necessary to handle the job in a different manner, and this will be more thoroughly discussed under the heading "Something Falls on Top of Tools, Locking the Jars."

As the cuttings are loosened from around the tools they should be bailed out and in order to do this, it will, of course, be necessary to keep a few feet of water above the tools.

If the hole is of such size or depth that a home-made spud cannot be used then a regular drilling-tool spud should be employed.

In using this tool it is screwed onto the bottom of a set of jars with stem above. Sometimes a light stem is used between jars and spud, but when this is done, a heavier stem should be used above.

In running a spud the cable is so let out that the jars strike on both the up and down strokes. It is necessary to get both the up and down jar in order to prevent the spud from sticking and also for the purpose of keeping the cuttings from settling.

In running, use short strokes unless heavy driving is required, in which case the stroke can be lengthened out. A careful "feel" should be kept on the drilling cable at all times to see whether or not the jars are working and at first sign of the jars locking the spud should be driven up and a new start made.

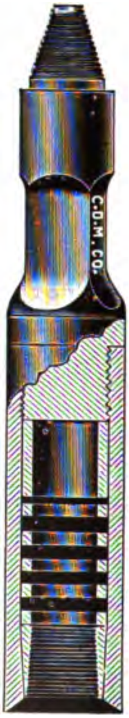
You will note from the cut, that the blade of spud is set over to one side of center and as long as the blade maintains this relative position in regard to the pin, the jars should not lock, but as it sometimes happens that the blade becomes bent or kinked, thus forcing the jars against side of hole, care must be exercised to see that the tools are not thrown sufficiently out of line to prevent the jars from closing on the down stroke.

Not only is the locking of the jars a dangerous condition in itself, but as it is necessary, in order to lock them, to throw the tools out of line, it thus throws an unsafe strain on the jars owing to the twisting action present.

After having cleaned around the tools as far as possible, with spud, bail out all water down to top of rope socket. This will not only remove the cuttings, but in case the tools are firmly fastened it will admit of much heavier up-driving owing to the fact that the presence of water above a set of fishing tools deadens the force of blow delivered by them. Of course, if the hole makes water in any amount it will be impossible to bail it dry, but as much water as possible should be removed.

You are now ready to make a try for the lost tools.

Combination Socket.



Section of Combination Socket.

The fishing tool to use is a combination socket, fitted with sets of slips for catching top of rope socket. The accompanying cuts show the appearance and construction of combination socket.

You will note from the cross-section cut, that the lower end of hole in socket, where the slips work, is made with a backward sloping taper, which conforms to the taper on back of slips. You will also note that a coil spring is carried above slips, this spring being for the purpose of holding the slips firmly in place while the socket is being lowered into the hole, also for forcing the slips down around the tool it is desired to catch.

Although the cut does not show it, the slips are made in three parts, this form of construction being used in order that the slips may work freely. As a rule, the upper end of slips have a groove cut around them on the inside, and in this groove a spring-tempered wire ring is carried, the ring being of such size that the slips are held firmly against the bevel so that the slips are not displaced while being set over the lost tool.

By again referring to cut you will note that the bowl of socket is screwed onto the upper part, or pin end, with straight threads. The socket is thus made so that it will be easy to place the slips in the bowl, also in order to make it easy to loosen the slips from the tool the socket has been used to catch. What is meant by this, is to loosen the slips after the lost tools have been brought to the surface. This will be discussed later.

A special wrench called a combination-socket wrench is made for setting up the joint at the bowl, but unless a very heavy stem is to be used above the jars, the special wrench is not needed, it being possible to set up the joint sufficiently tight with a pair of heavy chain tongs.

In using a combination socket it should always be placed below a set of jars, and if the tools in the hole are liable to be firmly fastened, a stem should be used above the jars. Where it has been necessary to chop up the rope, it is best to use a stem above jars, as the lost tools will probably have more or less cuttings and sediment around them which may make it hard to start the tools.

The size of stem to be used above jars depends upon the size of string of tools in the hole. As a rule, the stem above the jars should be about the same size as the stem on lost tools, unless extremely heavy driving will be required, in which case, the stem used for fishing should be of greater weight. In the oil fields they say "It doesn't pay to send a boy to mill," meaning that it doesn't pay to use a light fishing outfit where a big one is needed.

In lowering fishing tools in the hole, let them down carefully and when near the top of lost tools go very slowly so that the combination socket will not be jammed onto the tools. Should the fishing tools strike heavily on top of rope socket, it is very liable to break the slips.

After the combination socket has been seated on top of rope socket, let slack into the cable until the full weight of combination socket and lower part of the jars rests upon top of rope socket, this weight being sufficient to compress the spring in combination socket thus allowing the rope socket to pass up into the bowl of fishing socket. If the upper end of rope socket has been battered so that it is quite a bit over-size, it may be necessary to let more slack into the cable so that the combined weights of the full string of fishing tools can be used. If this does not result in forcing the socket down, use light down-jar blows. In jarring down care must be taken to use very light blows in order not to disarrange the slips. If the top of rope socket is not much battered or if no large obstacle is in the way, it should be possible to seat the fishing socket by this light driving, as the lower edge of fishing socket is inwardly beveled so that in driving, the rope socket will be forced upward.

If you find that the use of light blows does not have any effect, hoist the string of fishing tools and examine bottom of combination socket. If the bottom shows that the top of rope socket is not much larger than the hole in fishing socket, remove the slips, spring plate and spring from socket and again lower the tools in the hole, and try using a heavier down jar to force the bowl over rope soket. While it is possible to use heavier blows, after the slips have been removed than before, do not, however, drive with a long stroke as severe driving may result in cutting out the bottom of bowl so that the slips will not fit. If you succeed in forcing the socket up into bowl, hoist the fishing tools, replace the slips and again lower the tools. You should now be able, by the use of light blows, to seat the fishing tool over the rope socket.

After the fishing socket has been driven down, throw the hoist in gear and take a hard, steady pull on the tools. This is for the purpose of seeing whether or not the slips have taken hold. If they have, the pull will also tend to set them up tighter.

Now let slack in cable, place cable over the spudder or clamp it in temper screw, depending on depth of well, and so adjust the slack that the jars hit only on the up stroke. Begin by using light driving blows and continue using the light blows for some time. You can tell when the tools begin to start up, as the jars will hit on the down stroke as soon as the tools have been lifted a few inches.

As soon as you feel the down jar, take up the slack in cable, taking it up just fast enough to keep away from the down-jar.

After having driven up the tools for a distance of two or three feet, they should be loose enough to pull by a straight pull.

If the tools refuse to start by light driving, speed up the engine, which will result in much heavier blows. If the hole is of such depth that the spudder is being used, reverse the motion of spudder, thus obtaining the heaviest possible up jar as explained on pages 23 and 24.

If the tools start up and then reach a point where they seem to stick, slow up the engine, let sufficient slack into the cable so that the jars hit only on the down stroke and then drive the tools back to the point from which they started.

Now take up slack and again drive up on the tools. It will be found that by repeating these operations the tools will be driven up a little further each time and will at last reach a point where they can be driven up and finally loosened.

The above method applies where the tools are fastened by sand, gravel, rock cuttings or matter of similar nature, as in driving up the tools when surrounded by such substances, the material tends to wedge between the tools and the sides of hole.

When such wedging action occurs it can best be handled by backing off the tools, thus giving the material a chance to spread.

Should you attempt to force the tools upward in spite of the wedge, it will not only take more time than required by the other method, but, owing to the excessively hard driving needed, it throws much heavier strains on the tools and machine, than otherwise would be necessary.

If the top of rope socket is of such size that the bowl of combination socket cannot be forced over it by the use of safe driving blows, then measures other than described above must be adopted.

Broadly speaking, there are three methods to pursue:

First—To reduce the top of rope socket to such a size that the combination socket will pass over it.

Second—To use a fishing tool for catching the lost tools around the box collar of rope socket, or around or under the pin collar of stem.

Third—To ream the rope out of socket and to use a tool which will catch the socket on the inside.

Before deciding which of the above methods to use, an impression block should be run so as to determine the size of top of socket, also to ascertain whether or not the inability to seat the fishing socket is due to an obstacle in the hole.

To make an impression block secure a round piece of wood having a diameter of 1 inch less than the diameter of the hole in which it is to be used. The length of the piece should be about six times the diameter of the hole. Taper off one end of the block so that it will have the same shape as the pin of drill tool joints but about one-eighth of an inch larger. The idea is to make the end of piece of such shape that it can be screwed into box of rope socket or jars.

On the other end of block, tack on a piece of tin or thin sheet iron having a width of 3 or 4 inches and a length to reach completely around block and lap over a distance of an inch or so.

In tacking on the tin, so place it that about one and one-half inches project beyond the end of block, thus forming a cup on end of block.

Now place the block in a vertical position with cup end up, and into cup pour sufficient melted beeswax to fill it even with rim. Allow the block to remain vertical until the beeswax becomes solid, and then smooth off the surface of the wax by scraping.

If it is impossible to secure beeswax, soap or parafine may be used.

Parafine to be used, must be melted and poured the same as beeswax, but with soap, owing to its plastic nature, it is not necessary to melt it, it being possible to pound it into shape.

If it is necessary to use soap, forty or fifty nails should be driven in the bottom of block, the nails being driven down until the heads come within about one-half inch of the block. Now secure a sufficient number of bars of heavy laundry soap, such as Star or Irish soap, to completely cover the end of block and pound them down into the cup over the nail heads. Pound the soap until the different bars sort of run together and until a smooth surface is obtained.

After smoothing up the surface, the outer edge of tin should be slightly crimped inward, this crimping, together with the nails, being for the purpose of holding the soap in place.

Even when beeswax or parafine are used, it is a good plan to crimp the edge of tin, also to use the nails.

To run the impression block, the tools to use are rope socket and set of jars, the pin end of block being screwed into lower end of jars.

Some drillers use just the rope socket, but it is best to use the jars, especially if there is much water in the hole.

In screwing the block into the jars, use chain tongs on the block so that it can be set up firmly.

In lowering the tools into the hole, let them down carefully and just before reaching the top of the lost tools, go extremely slow. In order to determine the exact point at which the tools will strike, it is a good plan to mark the cable beforehand by tying a piece of string around it.

To get a good impression, let the block seat itself on top of the lost tools and then let enough slack into the cable to allow the weight of bottom part of jars to rest upon the block. Care must be exercised to see that the block does not strike the top of the tools but once, as otherwise a blurred impression will result.

If beeswax is used and the hole contains water, the wax may be so hardened by the water, and the water may so buoy up the tools that the weight of bottom part of jars is not sufficient to make a clear impression. To add more weight, let slack into cable until the full weight of jars rest upon the block. If this does not do the business, a slight down jar can be given. If, however, it is necessary to use a down jar, it must be confined to one blow, in order not to get more than one impression.

Next hoist the tools, doing so slowly and carefully so as not to loosen the wax nor tear the block loose from jars.

Should the block become loose, it can be recovered by filling the hole with water, which will float it to the surface. This same plan can be used for any piece of wood which may accidently fall into the hole, unless a heavy stream of water has been struck, in which case, it will be impossible to fill the hole to the surface, owing to the fact that the stream will absorb more water than you will be able, under ordinary conditions, to pour into it.

If there is no obstacle in the hole and if the top of socket has been properly cleaned off, a clear impression of the top of socket should be obtained.

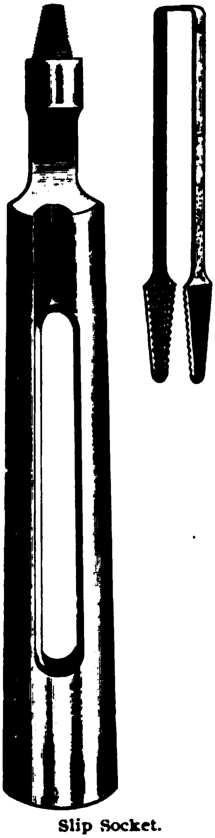
Carefully measure the impression and if it shows that the top of socket is not swelled over one-half inch over-size, it can be easily reduced with a Drive-Down Socket.

A Drive-Down Socket is made about the same length and has a great deal the appearance of a combination socket excepting that it is made in a solid piece. The bottom part is bored out on an inwardly sloping taper, so that when the socket is driven down over the top of rope socket, it will force the top of rope socket together.

The drive-down socket should be used on the bottom of set of jars with stem above. In using the socket, it is seated on top of rope socket and then sufficient slack let into the cable so that the jars hit only on the down stroke. If regular drilling jars having short stroke are used and the top of rope socket is quite a bit over size, it will probably require some little time to reduce it. If, however, long-stroke jars are used so that a full swing of the tools can be given, the operation should not require over fifteen or twenty minutes.

Should the impression block show that the top of socket is battered to such an extent that it cannot be reduced, then either the second or third method referred to above must be used.

If the diameter of hole is of such size that there is ¾ to 1 inch of clearance between the collar of rope socket and the sides of hole, then the tool to use is a slip socket. You will note from the accompanying cut the appearance and general construction of this tool.



Slip Socket.

Two slips are used in a slip socket, each slip being welded onto a small bar of steel about one and one-half feet long. The slip bars are usually fastened at the top by bolting them together, a piece of pipe being placed between the two bars so as to space them properly, the bolt passing through the pipe. The slips are held in place by slightly bending the upper ends, through which the holes are bored, thus causing the slips to press outward against the bowl of socket when the nut on bolt is drawn up tight.

The slip socket is used about the same as combination socket, excepting that in this case it is used for catching the collar instead of top of rope socket. Owing to the fact that there is no spring above the slips, as in combination socket, to force them into place after the socket has been set around the lost tools, the slips are made to take hold by jarring down very lightly, the jarring causing the slips to descend.

After a few light down jars, put a tension on the cable. This will cause the slips to take a firm hold, which can be made more secure by a few up-jar blows.

The procedure in recovering the tools is now the same as after the combination socket had been seated, excepting that with the slip socket it is impossible to drive down owing to the fact that there is no shoulder to drive against, as is the case when top of rope socket is caught.

If the space between the collar of rope socket and sides of hole is not sufficiently great to admit a slip socket, which must, of necessity, be made with a bowl of a thickness of at least three-quarters of an inch, then the third method advocated above must be adopted, unless the tools lost in hole are not firmly fastened, in which case there are three forms of sockets which can be used, namely, Horn, Long Friction and Collar Grab Sockets.

Horn Sockets are furnished in lengths of from three to four feet, being made up of a piece of extra heavy pipe welded onto a pin. The pipe is so cut that when welded, there is an inwardly sloping taper from the bottom upward. A slot is cut in the pipe, the slot beginning about six inches from the lower end and extending up to the weld.

Horn Socket.

The horn socket should be used on the bottom of a set of jars, but owing to the fact that its hold is only a fractional one, it is not necessary to use a heavy stem above it. In fact, many drillers use simply a rope socket and a set of jars above.

In using the socket, seat it over the tools by the use of down-jar blows. As the socket is driven downward, the tools are forced further and further into the inwardly sloping taper, thus wedging them firmly into the socket. While a horn socket is designed primarily for recovering tools which are not fastened in the hole, it will, nevertheless, stand quite a bit of up driving, and thus even though the string of tools is slightly wedged by the sediment around them, it may be possible to loosen them and bring them to the surface with a horn socket.

Another socket made very similar to a horn socket is the friction socket, which is quite a bit longer than horn socket, but which is used in exactly the same manner, and is constructed to work on same principle.

The extra length of friction socket makes it hold more firmly than a horn socket and thus it is often used to recover stems which are loose in the hole and which have joint collars of such large diameter that neither a slip socket nor a collar socket can be used.

In running a friction socket, owing to its extra length and thus its great holding power, it is best to use a light stem above the jars, so that in case it is impossible to loosen the tools, the socket can be driven off of them.

The third style of socket listed above, namely the collar grab socket, is made somewhat on the order of the friction socket excepting that the bowl has a wide slot cut from the lower edge upward for full length. Also at lower end, and about five to six inches from the bottom, an inwardly projecting edge extends outward from the walls for a distance of about three-eighths of an inch.

In operating a collar grab socket, it is driven down over the tools until the inwardly projecting edge comes below the joint collar. The idea is to get the projecting edge of the socket to take hold of tools at the offset which occurs just below the collar where the wrench squares are started.

As a collar grab will hold firmly, it should be used on the bottom of set of jars with stem above jars.

While the three types of fishing sockets described above, namely, horn socket, long friction socket and collar grab socket, are hardly ever used in recovering lost tools which are firmly fastened in the hole, nevertheless the writer has described their construction and operation at this point in order to make future explanations more simple, as no matter what the nature of the fishing job on which they are used, the principles of the operations of the sockets are as outlined above.

If none of the methods advocated in the foregoing pages for the recovering of the tools can be used, that is, if it is impossible to successfully use combination socket, slip socket, horn socket, long friction socket or collar grab socket, then it will be necessary to drill or ream the rope out of socket and use a tool which will catch the socket on the inside, this being the third method as listed on page 133.

In reaming out rope, a special type of flat drill is used. The drill is operated on the end of a line of pipe or tubing and the rope is reamed out by turning the pipe in the proper direction, which for ordinary pipe, having right hand threads, will be in a right hand direction. If in reaming, a rivet is encountered, it can be gotten rid of by cutting it off up close to the shell.

To cut off rivet, a circular cutter having an outside diamater one-eighth less than the inside diameter of socket neck should be used. The circular tool should have a sharp cutting edge and should be used on the bottom of the line of pipe used for operating the flat drill.

After cutting off a rivet it can be removed by lowering into the hole, on the end of sand line, a piece of magnetized steel, or by driving a piece of pipe into the neck of socket, the pipe being of such size that the rivet will become wedged into it.

After reaming out the rope, the socket is ready for the fishing tool, which is known as a twist drill spear.

A twist drill spear is made in the same form as a bull-dog casing spear excepting that it is, of course, much smaller, owing to the smallness of the hole in which it is to be used.

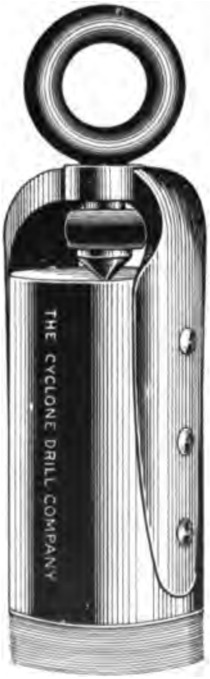
In operating spear, it should be used below a set of jars, with a heavy stem above jars. After securing a firm hold with the spear, drive up with light blows. Do not attempt to use full driving blows, as the spear must of necessity be made rather small and thus can be broken with comparitive ease.

If the tools do not start up after a few minutes driving do not get impatient, but keep the tools on a light up jar, as the continued application of these light strokes will in time start the tools unless they are very securely fastened.

If after a couple of hours of driving, the tools do not seem to be loosening, increase the force of blow a small amount. Continue this kind of driving for a couple of hours and then if no results are obtained, again increase the strength of blow. Continue this procedure until either the tools come loose or else the spear breaks.

Should the spear break without loosening the tools, it will indicate that the tools are very firmly fastened and thus preparations must be made for a stubborn fishing job.

As tools have been proven to be firmly fastened, it will first be necessary to put them in such shape that they can be taken hold of with a fishing tool which will admit of heavy up driving and then something done to loosen up the tools as much as possible.



Casing Swivel.

To prepare the tools so that they can be caught with fishing tools, it will be necessary to mill off the top of rope socket so that a combination socket can be used, and to loosen the tools it will be necessary to run a spear around them.

A milling tool for handling the above work is made somewhat on the order of a drive down socket, it having the bottom bored out on an inwardly sloping taper. Unlike the drive down socket, however, the inside of tapered bowl is provided with flutes so that when the milling tool is revolved, the top of socket will be cut away.

In using the milling socket it is screwed onto the lower end of a line of pipe, the size of pipe to be used being in proportion to the size of socket to be reduced. As a rule two inch standard pipe will be of ample size.

In operating the milling socket it should be lowered until it rests upon top of rope socket, and to the top of pipe, which should extend some eight or ten feet above surface of ground, must be attached some sort of device which will allow the pipe to be revolved without twisting the drill rope, which will be used for sustaining the weight of the pipe.

A water swivel as shown under "Hollow Rod Tools" is an excellent device, but if you do not have one of these at hand or are unable to readily procure one, it is possible to use a home-made casing swivel for the purpose.

The cut on opposite page shows the construction of one of these swivels so clearly that further description is not necessary.

After seating the milling tool on top of rope socket and connecting drill rope to swivel, take up slack in cable until nearly the full weight of pipe is supported by the cable. Next attach some sort of appliance to pipe so that it can be revolved. The "Casing Pole and Rope" shown on page 42 will serve the purpose nicely. Now revolve the pipe in right hand direction, letting off slack as needed.

The pipe should be marked at some point so that an accurate record can be kept of the progress made. It might be added that in setting up the joints on pipe connected with milling tool, they should be set up as tight as possible, as otherwise the various joints are liable to screw together during the milling operations, thus giving a misleading record of the work.

After having run the tools until you think the top of socket sufficiently reduced, remove the pipe from the hole and lower the combination socket (first removing the slips) so as to see whether or not it can be seated over the rope socket.

To make sure of this point, a small amount of stiff clay should be placed in upper part of fishing socket bowl, thus making of the socket a sort of impression block, which will clearly indicate whether or not the rope socket passes up into fishing socket bowl.

The advantage of the milling tool over the drive down socket for reducing the top of a rope socket is that the milling tool can be made with a much thinner edge at bottom of bowl, thus permitting it to be used on jobs where the drive down socket would be of no value owing to the thickness of its walls. Thus it is necessary to make the walls of bowl of drive down socket at least three-quarters of an inch thick in order to stand the heavy strain thrown upon them, and therefore the walls of socket take up at least one and one-half inches of the diameter of the hole.

On the other hand, the lower edge of bowl of milling tool need not be over one-fourth of an inch thick so that the walls do not take up over one-half of an inch of the diameter of the hole.

To illustrate what is meant by the above, we will suppose that a rope socket having a neck 3¼ inches in diameter is lost in a hole 5⅝ inches in diameter. If the top of socket is not swelled to a size greater than 4 inches, the drive down socket can be used, as there is left a space of 13/16 inch between the top of socket and sides of hole, this being just sufficient to allow a drive down socket with walls ¾ inch thick to be run. However, if the top of socket is swelled to such an extent that it is larger than 4 inches, then the drive down socket will be of no benefit and it will be necessary to use the milling socket, which having as it does a lower edge only ¼ of an inch thick, can be used for reducing the top of a socket when the space beween the top of socket and sides of hole is no greater than ½ of an inch.

After having reduced top of rope socket to proper size, the next step is to loosen the tools by running a spear.

A spear is made the same as the spud illustrated on page 129 excepting that the spear is longer. Spuds as a rule are about eight feet long, while spears are made in all lengths from twenty to eighty feet.

The length of spear to use depends upon the length of string of tools in the hole, also upon whether or not it is necessary to drive the spear to the bottom of the hole. If any hard substance such as a large nut, bolt, monkey wrench, etc., has fallen into the hole and is wedged around the tools the spear should be of such length that it can be driven completely to the bottom so that the obstruction will not wedge the tools when they start up.

Also in some kinds of drilling, the cuttings settle around the tools very solidly and under such circumstances it is necessary to drive the spear to bottom in order to loosen up this solid mass.

All cuttings will settle more or less solidly, but there are certain limestone cuttings which, when allowed to settle, will kind of cement together and become almost as hard as the original rock.

Probably the most treacherous of all cuttings are the cuttings, or rather sludge, made by drilling in blast furnace slag. Quite a lot of drilling is now being done in this kind of material, for blasting purposes, and should you ever attempt any such work, you must be extremely careful about leaving the tools upon the bottom of the hole, even in drilling operations, as slag sludge solidifies so rapidly that it does not require over five or ten minutes to become so hard that the tools cannot be removed from the hole.

As long as the tools are kept in motion, no trouble will arise, but should it become necessary to make any adjustments, which will require the shutting down of the machine, the tools should be hoisted from the hole or at least hoisted above the sludge.

Now to return to running the spear.

If conditions are such that it is thought necessary to run the spear to the bottom of hole, a spear having a blade about 3 feet longer than the total length of lost tools should be used. That is, if the total length of tools is 25 feet, the blade of spear should be about 28 feet.

The method of running a spear is practically the same as that used in running a spud, as described on pages 129 and 130. Owing to the long length of a spear blade, it is sometimes best to first use a spud in starting around the tools, and then, after the spud has been driven down for 6 or 7 feet, the spear put on in its place. The advantage of this method is that the start of 6 or 7 feet will hold the spear solidly, thus reducing the liability of kinking or springing the blade.

As the long length of blade of spear makes the spear drag heavily, it is necessary to use a very heavy stem above the jars and, as stated under instructions for operating spud, it is necessary to have the jars strike on both the up and down strokes. In order to get best results the jars used should have a stroke of at least 18 inches.

In driving the spear, quite a bit of cuttings will be made, as the walls of the hole will be more or less chipped off, also as the spear approaches the bottom of hole the sludge and cuttings which were originally in the hole will be stirred up.

By keeping about 10 or 15 feet of water above the top of lost tools, it is possible to bail out some of the cuttings and this should be done from time to time.

Where the holes are not over 300 or 400 feet in depth or even on holes of greater depth, where the cuttings settle rapidly, some drillers jet the cuttings out of the hole by forcing a stream of water down around the tools and washing the cuttings to the surface.

Owing however, to the time consumed by using the jetting outfit, the writer does not recommend its use excepting after the spear has been run for the last time, and it is desired to thoroughly clean the hole preparatory to using the fishing tools. Even then it is not necessary unless the cuttings are of such nature that they solidify rapidly upon settling.

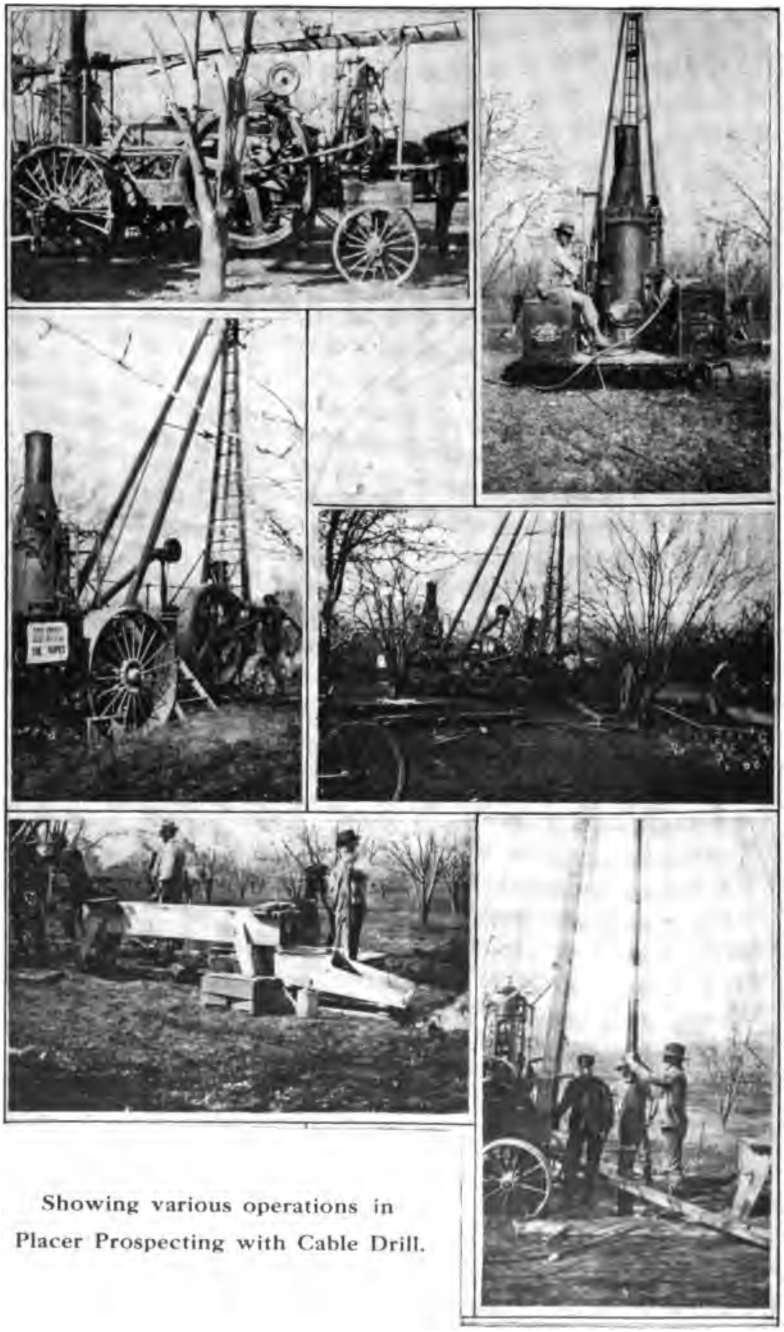
After having driven the spear completely around the tools and down to the bottom of tools, clean out the hole thoroughly.

You are now ready to run the fishing tools which should consist of combination socket, with jars above and heavy stem above the jars. Owing to the fact that the tools have been loosened by running the spear, no trouble should be experienced in starting them. The method to be followed out is the same as outlined on pages 130, 131 and 132.

You will note under the heading "Cable Breaks," that a great many different methods for recovering the tools have been described. While it is seldom, if ever, that you will be called upon to use all of the plans outlined, nevertheless, the writer has listed them, so that you may know the different tools and procedures available.

In figuring on a fishing job, it is necessary for the driller to know the various methods which may be used and then to use first, those methods which, should they fail, will not further complicate the recovery of the tools. Thus, if the tools become firmly fastened in the hole and the drill cable parts, it would be very bad judgment to attempt to recover the tools by use of a rope spear, as under such circumstances there is great danger of adding to your troubles by having the rope spear as well as the tools to fish out.

While the various methods described in the preceding instructions are so arranged that there is not much danger of complicating matters, should the methods fail, still they can be safely re-arranged to a greater or less extent, according to the conditions to be met.



Showing various operations in Placer Prospecting with Cable Drill.

Thus some drillers, after determining by the use of an impression block, what kind of fishing tools will be needed, do not attempt to recover the lost tools until after they have loosened them up by running a spear around them. These are matters which must of necessity be left to the decision of the driller as it is very rarely that the same conditions are met in different fishing jobs.

A good test to apply to each method, before using it, is to ask yourself whether or not the failure of the method will further complicate matters. If after careful thought you fail to see any danger ahead, and the method is one which can be used for taking care of the work at hand, then the thing to do is to go after it.

## Rope Pulls Out Of Socket.

This sometimes causes fishing jobs but not very often.

In handling this condition one or more of the methods given under "Cable Breaks" apply, the method to be recommended depending upon circumstances.

If the tools are firmly fastened it will of course be necessary to use a fishing tool which will admit of heavy up driving, but if the cable pulled out while the tools were working freely, it may be possible to recover them with a horn socket or a long friction socket.

## Joint Comes Unscrewed

In a full string of tools made up of rope socket, set of jars, auger stem and bit, there are three joints which may become unscrewed, namely, the joint between the rope socket and jars, the joint between the jars and stem, and the joint between stem and bit.

Should either of the two top joints become unscrewed, the fact becomes instantly noticeable inasmuch as the removal of the weight of stem and bit causes the engine to speed up and the cable to become slack.

In case the engine is equipped with a governor thus maintaining the same speed whatever the load, you will of course not be able to notice any variation in speed when the joint becomes unscrewed, but if you are paying strict attention to business and are keeping careful watch of the outfit, you should be able to instantly detect the trouble by the slackness of the cable.

While slackness in the cable may of course be due to several causes besides joints becoming unscrewed, nevertheless it indicates an unusual condition in the hole and thus the engine should be instantly stopped, or at least the spudder or walking beam, whichever is being used, should be stopped and the tools hoisted from the hole.

If an examination proves that the trouble is due to an unscrewed joint and the tools have been stopped soon enough to prevent the threads from becoming battered, the lost tools can be secured by screwing the joints together down in the hole.

This is done as follows:

Lower the tools remaining on cable, until they come within a few inches of the pin of lost tools. Next twist the cable 15 or 20 times in a left hand direction and hold the twist in the cable. Now lower the tools until the box of tools on the cable seats itself lightly over the pin of lost tools. After making sure that the box is properly seated, slowly let the twist out of cable. The unwinding of the twist should cause the joints to screw together.

To assist in setting up the joint, the tension on the cable should be varied, that is, a slight strain should be put upon it, this being followed by letting in slack. Repeat this procedure several times and if the tools have been properly handled, the joint should now be set up sufficiently close to allow the tools to be hoisted from the hole.

The above method can be used in holes of depths up to 500 or 600 feet or even deeper, but on very deep holes it is best to use a collar socket or a slip socket and catch the lost tools around the collar. If the hole is not of sufficient diameter to use either of these tools, then a combination socket fitted with slips for catching the pin should be used.

If, however, you do not have any of the above fishing tools on the job, it is best to attempt to recover the tools by screwing the joints together as first described, rather than wait for fishing tools.

If you are unable to make the joints screw together by use of the cable, the tools can be disconnected from the cable and lowered into hole on the end of a line of pipe.

The advantage of using the pipe is that you have a sure control of the tools, thus making it possible to determine when the joints are screwed together.

If you have no pipe-joint substitute as shown on page 119, then the easiest method of handling the work is to connect the pipe to the rope socket by cutting off the cable about two feet above top of rope socket and then inserting this two foot piece of cable into the end of a piece of pipe.

The cable can be fastened into the pipe by having holes drilled into pipe and rivets driven through the same as in patent socket shown on pages 10 and 11.

To make a good job of it the pipe, directly above the rope socket, should be of such size that the cable fits into it snug, and 5 or 6 one-half inch rivets used.

For lowering the tools into the hole, pipe 1 to 1½ inch in diameter should be used, where the tools are of small or medium size.

This pipe can be connected to the larger piece of pipe which is used directly above the rope socket, by use of a steel reducer.

If the bottom joint comes unscrewed, its effect is not so instantly noticeable, as when either of the two top joints come loose, and thus it is very probable that the box of stem and the pin of bit will be ruined before the driller becomes aware that anything is wrong. If, however, the driller is paying strict attention to business he should be able to tell that something is wrong within five minutes after the bit comes loose. Especially is this so in holes up to 300 to 400 feet in depth, where the proper tension is kept on the cable and the cable is being let out but a little bit at a time.

A good driller always keeps note of the cutting speed of the tools and when this speed decreases he knows that one of three things has happened ; —that the material has become harder, that the bit has become suddenly dulled, due to breaking off corner or edge or that something is wrong in the bottom of the hole.

As the loosening of the bit joint stops further drilling progress very suddenly, its effect is very noticeable to an experienced driller. If, however, you are a new man at the business, not having been drilling long enough to make the sound, the feel and the action of the drilling cable, sort of second nature to you, you will probably not note the change for some time, and thus the bit and stem will be considerably battered before the tools are stopped.

As the ability of being able to judge conditions in the hole, by the evidence afforded by the cable is one of the most valuable assets possessed by a driller, a man starting in to learn the drilling business should make it a point to acquire this ability at the earliest possible date.

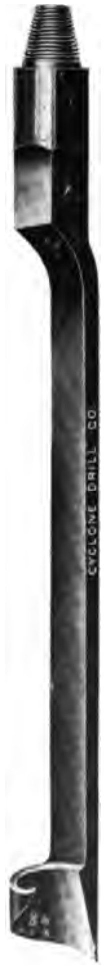
Probably the best and quickest way to learn, is to drill by the watch. To do this, hang up a watch somewhere around the machine in such a position that it can be readily seen by you when you are standing beside the drill hole. Now make note of the amount drilled each five or ten minutes and compare these amounts from one unit of time to the other. As the number of inches drilled in five or ten minutes is not very great, it will be necessary to pay very close attention to the work in order to determine the amount drilled. For the first two or three weeks you should keep track by tying a string around the cable at a certain point and measuring from this string. After following this method for two or three weeks, do away with the measuring stick and learn to estimate the inches drilled by the amount of cable let out. Continue this estimating by the watch for at least six weeks or two months, at the end of which time it will probably not be necessary to longer use the watch as you will be able to detect almost unconsciously the slightest change in drilling rate.

It may appear to you that the following out of the above instructions involves more trouble than the information learned is worth, but as it is necessary for a driller to learn the sound, the feel and the action of the drilling cable before he is really a driller and as the method advocated above will teach it to you in the shortest possible time, the writer would suggest that you follow it carefully.

What has been said above refers to drilling in rock only.

Now to return to the fishing job.

In fishing for a bit which has become unscrewed, the fishing tool may be a horn socket, a long friction socket, a collar socket, a slip socket, or a combination socket. If a combination socket is used, it should be fitted with slips for catching the pin of bit.



Bit Hook.

If the blade of bit is of such small size that the bit has a chance to lean over in the hole or if the tools have been run on it such a length of time, that the top of bit has been driven into the side of the hole, then it will be necessary to straighten up the bit, so as to be able to seat the fishing socket.

If the cuttings have not had time to settle solidly around the bit, the bit can be straightened up by the use of a bit hook. The accompanying illustration shows the construction of this tool. In operation, the bit hook is used on the bottom of a set of jars and is driven down around the shank of the bit, so that the hook of the bit hook, catches around collar of bit, thus forcing the bit out from the wall.

It sometimes happens that after the hook has been removed the bit will not stand straight, but falls back against the wall of hole in such manner that a fishing socket cannot be set.

This trouble can be overcome by placing some fine slack coal in the hole before running the bit hook, the coal serving to hold the bit erect after it has been straightened up.

Another method is to pour small potatoes or turnips in the hole the vegetables serving the same purpose as the slack.

The amount of "filler" depends upon the amount of space around the bit; if coal, about enough to come half way up the bit, if vegetables, enough to come to the top of bit.

If the lost bit has been in the hole for a considerable length of time, thus giving the cuttings time to solidify, it will be necessary to spud around the bit before running the fishing socket. The tool for this purpose is the spud shown on page 129. The spud can also be used instead of the bit hook for straightening up a bit which leans in the hole.

To straighten up a bit with a spud the spud should be driven down beside the bit to the bottom of the hole, the action of the spud being such that the bottom of bit is driven over, thus forcing the top of the bit out in line with the hole.

If the bit falls back after being straightened up with a spud, the coal or vegetable remedy can be used.

## Jars Break.

Owing to the link construction used in a set of jars, the breaks which can occur may present a wide variety of conditions. By this is meant, where the breaks have to do with the link part of jars. Where the breaks occur at the squares or at the pin, the conditions are practically the same as when such breaks occur in a stem, and thus such troubles as snapping off of pin and breaking of squares will not be discussed at this point, being reserved for discussions under the heading "Stem Breaks."

There are three main causes for jars breaking in the reins, namely, poor workmanship or bad material, jars become too much worn, and side strains caused by crooked holes.

Where either poor workmanship or bad material is the cause, the break will generally show up within 3 or 4 weeks after starting to use the jars. If no trouble occurs within this time, it is pretty conclusive evidence that the jars are all right. Where jars are purchased from reputable drill manufacters, it is very rarely that a defective set will be found. In fact, so complete have become the facilities for making drilling tools and so expert have drilling-tool workmen become that is very seldom, if ever, that defective jars are turned out by them.

As explained on page 99, where jars become worn down in the heads, until only 2 or 3 inches of metal remain above the base of the tongue, they should be thrown aside. If they are used after becoming worn down, to this point, a risk is being run, the risk becoming greater the longer the jars are used. Not only does the risk of breaking become greater, but the seriousness of the fishing job which will be caused is very liable to become greater. What is meant by this is that a much meaner fishing job is liable to happen when the jars break after becoming worn down below the limit set above, than if they break before. The reason of this is, that the jars, when greatly worn, are liable to break right at the base of the tongue and as the reins at this point are thin enough to allow them to pass through the slot of the opposite rein, a break at this point may result in allowing the broken piece to slip out and wedge itself between the tools and walls of hole. On the other hand, if the jars are not allowed to wear down too far, the liability of a break occuring of such nature, that the broken piece can fall out from between the reins, is very small. In making the reins, this point is taken into consideration, and you will note by examining a set of jars, that the width of the reins for their full length down to base of tongue is greater than the width of slot between reins.

The third cause of broken jars, namely, a crooked hole, is probably accountable for more breaks than both of the above named causes put together.

When a break results from a crooked hole, the break nearly always occurs on the up stroke of the tools. It does not require a very heavy strain to snap off a set of jars, when they are being operated in a crooked hole, owing to the fact that in lifting the tools, a wedging side strain is thrown upon the reins. Thus, if you find that a hole is becoming crooked and you do not want to take the time to true it up, you must run the tools on a slow motion until after the top of jars pass below the crook. It is, of course, much safer to ream out and straighten up the hole, but if the hole is a very shallow one and you do not have to drill much further, it may be possible, by using extra care to finish it up without getting into trouble.

As stated at the beginning, many different styles of fishing jobs can arise by the breaking of the reins and as it would be impracticable to attempt to cover all cases, the following typical cases will be referred to, as from them, it will be possible for you to figure out methods for handling all other kinds of breaks.

In order to avoid confusion, the cases will be taken up and classified in the following order.

| | |
|---|---|
| Class A | Top reins break off even, close to cap. |
| Class B | Top reins break off uneven. |
| Class C | Top reins break off through tongue. |
| Class D | Bottom reins break off even, close to cap. |
| Class E | Bottom reins break off uneven. |
| Class F | Bottom reins break off through tongue. |

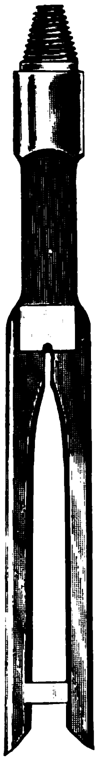
**Class A.** If the reins break off even, just at base of cap, the fishing tool to use is a slip socket or a collar socket for catching the outside of reins.

If the jars are of such size that you do not have sufficient space around them to run a slip socket, a horn socket or long friction socket can be tried. If the tools are loose in the hole, the horn socket or the long friction socket may take a firm enough hold to lift them, but if they are fast it will be necessary to use a fishing tool for taking a hold which will stand heavy up-driving.

In order to determine the kind of tool to use, run the impression block. If after an examination of the block, you are not able to figure out a method for catching the tools, make a sketch on a piece of paper, showing the exact conditions as revealed by the impression block and send this to your drill manufacturer. Mark all the dimensions on the sketch, also giving the diameter of hole, and the manufacturer can then make up a tool to suit the conditions.

**Class B.** If the reins break unevenly, leaving one rein extend up past the tongue of lower reins, while the other rein breaks off somewhere below the head of lower rein, then the fishing tool to use is a side latch jack, which is so constructed that it can be shoved down along the side of the lower reins, catching them just below the head.

If both the reins are broken off down close to their lower end, thus exposing the slot below the head of lower reins, the tool to use is a jar latch socket or as it is sometimes called, a boot jack.



Jar Latch Socket.

You will note the construction of this tool from the accompanying illustration. The piece connecting the lower ends is made on a hinge, being so constructed that when the boot jack is forced down over the top of lower reins, the hinged piece snaps into place as soon as it comes below the lower head. As the hinged piece works against two heavy shoulders, the tool will stand very heavy driving.

There is another type of fishing tool made for handling Class B. This tool being called a jar tongue socket. As its name implies, the tool is used for catching the tongue of lower reins.

**Class C.** As already stated, the breaking of the reins through the tongue may cause a very mean fishing job by allowing the broken piece to fall from between the lower reins, thus wedging the tools.

You will, of course, always be able to determine when the break occurs through the tongue, as the piece of jars brought to the surface will reveal the nature of the break.

While it does not always happen that the piece falls out, when the break occurs through the tongue, nevertheless, in going about the fishing job you must figure that the piece may fall out and thus go about the work so as to make yourself as safe as possible.

Thus instead of using a boot jack for fishing, a jar tongue socket should be used, as it may be necessary to break the hold of the fishing tool and when the boot jack is used this is something hard to do.

If the piece remains in the jars no trouble should be experienced in recovering the lost tools, but if the piece falls out, it will be necessary to get rid of it before going ahead with the work.

If the jars fit the hole very snug, it will, unless the break is one that rarely happens, prevent the piece from falling down between the tools and the side of the hole.

However, it will not prevent the piece from dragging and catching against the walls and thus if it is possible to do so, the piece should be so fastened that it will not cause any trouble on the way up. Especially should an effort be made to fasten the piece if considerable drive pipe has been used in the hole, as the piece is very liable to catch on the bottom of pipe, thus making it necessary to pull the pipe, a job made doubly troublesome owing to the fact that the cable and tools are down in the hole.

Of course, if any gravel or other ravelly material lies above bed rock, it will not be feasible to pull the pipe even if it is possible to do so, inasmuch as the loose material will cave in around the hole.

If the tools can be brought up to the bottom of the pipe, it may then be possible to crowd the piece far enough in between the reins to allow it to pass up into the pipe. To do this, a tool having the lower end shaped somewhat like the lower end of bit-straightening hook, illustrated further over, should be used. The tool can be made out of a bar of iron ⅜ inch by 2 inches by 5 feet long and should be used on the bottom end of a line of ¾ inch pipe.

By twisting the hook around and under the broken piece, it can be forced into place between the reins and held there until it passes lower end of drive pipe.

After getting the tools started in the drive pipe no further trouble should be experienced.

If, however, the piece catches in the pipe, it can be loosened in the manner just described.

If the hole in which the tools are lost is of such size that the broken piece slips from between the reins, down by side of the tools, then it will be necessary to run a spear around the tools and drive the piece to the bottom of the hole. After having driven the piece to the bottom, the lost tools can be caught with either a slip socket, jar tongue socket or boot jack.

Some drillers think it a waste of time to drive the piece to the bottom of the hole, arguing that the time consumed in running the spear would be sufficient to jar the tools out of the hole. This is the wrong way to look at a fishing job, as a driller should so lay out his work, that each step taken will tend to make the recovery of the tools easier.

As long as you are running the spear, you know that you are not complicating matters, and the further down the piece is driven, the easier will the tools come when finally caught with the fishing socket.

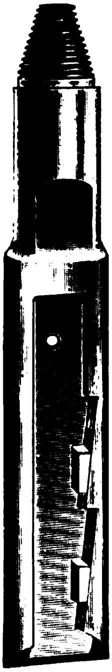
On the other hand, if you attempt to jar the tools out of the hole, regardless of the position of the lost piece, you are working more or less in the dark and while you may, and probably can, drive the tools past the piece, still it is taking chances, and chances are things that good drillers keep as far from as possible.

**Class D.** When the bottom reins break off even, close up to bottom cap, the method to follow out is the same as under Class A, excepting that the fishing tools will take hold of outside of bottom cap instead of outside of reins.

If all the methods advocated under Class A fail, send your impression block measurements to the manufacturer as advocated.

**Class E.** When the bottom reins are broken off unevenly, there are three types of fishing sockets which may be used, namely, the center jar socket, the side jar socket and the jar socket.

The center jar socket is used when the reins are broken off rather close to the tongue. The accompanying illustration shows the construction of the socket, and will also make it easy to figure out the manner in which the socket works.



Center Jar Socket.

The opposite side of socket, not shown, is made in the same manner as the side illustrated.

To operate the socket it should be lowered between the upstanding broken reins, so that the slips can take a firm hold of each rein.

Both the side jar socket and the jar socket are used when one of the reins is much longer than the other, they being so constructed that they catch but one of the reins.

**Class F.** A break through the tongue of the bottom reins is very liable to result in leaving a loose piece of steel in the hole. If the piece broken from the lower reins comes up with the top reins, then the fishing tool to use is one of the three sockets recommended for handling Class E, the socket to be used depending upon the nature of the break.

If the broken piece does not come to the surface, then it is necessary to either fish it out of the hole or else drive it to the bottom of the hole.

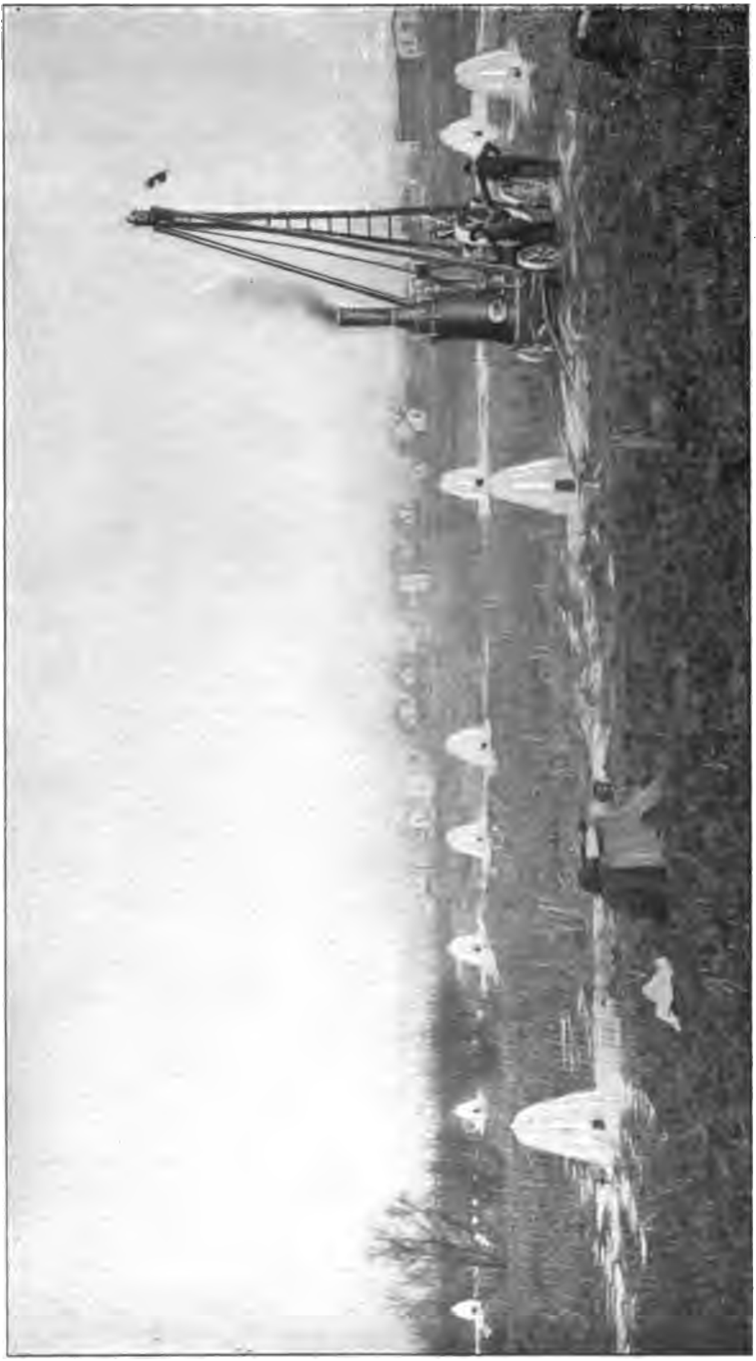
A strong effort should first be made to remove the piece. To go about the work intelligently, the impression block should be run so as to determine the position of the piece in the hole.

In fishing for the piece an alligator grab should be used and if the block has shown that the piece is down along the side of the lower reins, the jaws of the grab should be bent to one side so as to reach in after it.

An Alligator grab is operated below a set of jars with rope socket above.

If the hole is a shallow one, a home-made grab operated on the end of a line of pipe can be used. The nature of the grab to be made depends upon the shape of the piece, also upon the position of the piece in the hole, as revealed by the impression block, and thus the making of the grab must be left to the reader's ingenuity.

After removing the broken piece, the fishing job should be handled as recommended in the beginning of Class F.



A part of the water supply of the City of Canton, Ohio. The 10 flowing wells shown above are made in gravel and produce 7,500,000 gallons per 24 hours.

## Stem Breaks.

In order to avoid confusion the different stem breaks will be classified, as follows:

| | |
|---|---|
| Class A | Pin snaps off. |
| Class B | Stem breaks through top square. |
| Class C | Stem breaks through bottom square. |
| Class D | Stem breaks through body. |
| Class E | Box breaks. |

**Class A.** The snapping off of pin on stem will leave a collar standing up and thus the fishing tool to use is either a collar socket or a slip socket. If the hole in which the tools are lost is too small to admit either of the above fishing sockets, then it will be necessary to use a horn socket or a long friction socket, preferably the long friction socket.

If the tools are so firmly fastened that they cannot be recovered by using either of these sockets, then it will be necessary to use one of the three following methods, namely:

Reduce the collar until it is of such size that a fishing socket can be used.

Mill a pin on the end of stem.

Ream the hole to a size which will admit of the use of a fishing socket.

To reduce the collar a tool called a rasp is used. Two types of rasps are made; one known as a side rasp, the other known as a two-wing rasp.

The side rasp is made on the order of a spud as shown on page 129 the difference between the two being that the blade of rasp at lower end is made somewhat thinner than a spud blade and is also provided with flutes or teeth, or as they are called by drillers, "whiskers."

The two-wing rasp is made in the same manner as the side rasp, excepting that two blades are used instead of one, the two blades being set opposite each other, so that in operation, two sides of the collar are being cut down at the same time. When the collar fits very snug in the hole, the side rasp will prove more satisfactory, as it can be operated in a smaller space than the two-wing rasp. However, the two-wing rasp is more rapid in its work and thus when conditions are favorable for its use, it is the more satisfactory tool.

A rasp either two-wing or side, is operated in about the same manner as a spud and thus the instructions for operating spud, given on page 129 apply to the rasps.

After operating the rasp a short time the impression block should be run so as to determine the size and condition of collar. As soon as the collar has been sufficiently reduced the fishing socket can be run and the tools recovered.

In running the fishing socket, it must, of course, be placed below a set of jars, with a stem above the jars. This advice is probably unnecessary, owing to the fact it has been so often stated that a stem must always be used above the jars on difficult jobs, but it is added for fear that the former instructions might be forgotten.

The second method, under Class A, namely milling a pin on end of stem, is one that involves a high degree of skill and thus should never be attempted by anyone not experienced in the work. Inasmuch as in ordinary water-well drilling it is very probable that you will never have an occasion to do this kind of work, and also owing to the fact that if the occasion does arise, the work will have to be handled by an expert, the writer does not believe that it will be of any advantage to you to enter into further discussion of the method, it having been referred to more to illustrate the perfection to which fishing tools have been brought, than to instruct you in its use.

The third method under Class A, namely reaming the hole, might be termed a method of last resort and should not be used until after all other methods have failed. In fact, under certain conditions, it is impossible, from an economical standpoint, to ream a hole. Thus, if the hole has not been cased, that is cased on the inside of drive pipe, and a considerable length of drive pipe has been driven through material which contains a large amount of sand and gravel, it would probably be more economical to lose the tools than to attempt to recover them, if the recovery required the reaming of the hole, which, under conditions as outlined above would require the pulling of the drive pipe and the driving of pipe of larger size. If however, the hole has been cased inside the drive pipe, and the casing is in such shape that it can be pulled then it may pay to pull the casing and ream the hole on down from the point where the casing was seated. Also, if only a short line of drive pipe has been used, or if the walls of hole in the material above bed rock are such that they will stand without casing, it may be an economical proposition to pull the drive pipe and ream the hole.

In reaming a hole in which there are lost tools, it is necessary to first cover up the tools, so that the loose material and cuttings will not settle around them. For this purpose a piece of burlap or canvas should be used, the piece being of sufficient size to fill the hole for a distance of about one foot, after being firmly tamped into place. Before placing the packing in the hole, the hole should be filled with water up to the top of tools, the water serving to prevent the plug from being driven down around the tools.

As the pulling of pipe and casing and the reaming of a hole will be discussed further over, these operations will not be gone into more fully at this point.

After having reamed the hole down to the top of the canvas plug, the hole should be cleaned out very thoroughly and the plug removed. To remove the plug a short, sharp spear with a short barb close to the end should be used. The spear can be arranged to be operated on the end of a line of pipe or can be provided with a pin joint so as to be operated below a set of jars.

As soon as the plug has been removed, the hole should be reamed down to the top of the tools and then a spud run down around the tools for a distance of 2 or 3 feet.

The running of the spud should enlarge the hole around the stem to such size that a slip socket or other appropriate fishing tool can be used.

**Class B.** When a stem breaks off at the square, the fishing tool to use is either a horn socket, a long friction socket, a slip socket or a square socket.

A square socket is made similar to a slip socket excepting that the hole in bowl of square socket is made square instead of round.

The handling of a fishing job caused by a broken square at top of stem is practically the same as when the pin snaps off and thus the instructions found under Class A apply in the present case.

**Class C.** The breaking of stem through the bottom square is liable to present conditions similar to the unscrewing of the bottom joint referred to on pages 145 and 146 and thus the writer would refer you to the above pages. He would also refer you to pages 153 and 154 regarding the use ot rasps in reducing the size of a lost tool, as it may be that the tools will be run for a considerable time after the break occurs and thus quite a bead hammered on them.

The fishing tools which can be used are horn socket, long friction socket, slip socket or a collar socket.

As the weight of lost tools is not great, being only a bit and box, the horn socket will probably be the best tool to try first.

If the tools lean to one side, they can be straightened up as described on page 146, or if the cuttings have settled, the spud should be used.

**Class D.** The breaking of a stem through the body hardly ever occurs until after the stem has been used for quite a while and the steel has become crystallized. The fishing tool to use depends upon the location of the break, and the nature of the same. If the break occurs near the bottom of stem and the tools are run sufficiently long to batter a bead on the end, then it may be necessary to use the rasp for reducing the stem to a size where it can be caught. It may also be necessary to use a spud in case the tools have been on the bottom for some time.

The fishing tool to use may be a horn socket, a long friction socket, a slip socket or a collar socket.

**Class E.** When the box on stem breaks, the conditions presented are very similar to those occasioned by the unscrewing of lower joint in drilling tools and thus the instructions given on pages 145 and 146 apply in this case.

## Bit Breaks.

The breaks which occur in a bit are usually at the pin, at the weld or at the cutting end.

The snapping off of the pin presents fishing conditions very similar to the unscrewing of bottom joint, excepting that in this case the pin is broken off.

If the break is detected within a few minutes after it occurs, the bit can easily be removed by the use of a horn socket or a long friction socket.

If the tools are run for quite a while after the break occurs, it may be necessary to use a rasp for reducing the top. It may also be necessary to use a spud for driving down around the bit, not only for loosening it up but also for straightening it up as well.

In fishing for a lost bit, a horn socket or long friction socket is generally used.

However, if the top of collar is not expanded or has been rasped down to proper size, and the hole in which the bit is lost is not too small, it is possible to use either a slip socket or a collar socket.

The breaking of a bit through the weld is a trouble which seldom occurs on light tools, but where it does occur is liable to make a very mean fishing job. If the break is detected immediately after it takes place, the broken bit can be easily recovered by the use of a horn socket.

If, however, the tools have been run for some time, the bit may be so battered that it almost fills the hole, thus making it impossible to seat a fishing tool.

If you are unable to get a horn socket over the bit it will be necessary to drive a spud down around the bit. This will make sufficient room to use a rasp so that the top of battered bit can be reduced. As soon as it is reduced, the horn socket can be used.

When a bit breaks at the bottom, the trouble can almost always be traced to overheating of bit when it is being dressed or tempered. As a rule the piece breaking off, or as drillers say, "spalling off," is not large and can be drilled up. However, it sometimes occurs that a large chunk spalls off and when this occurs it will be necessary to recover the piece before proceeding with the work.

When it is discovered that there is a large piece of bit steel in the hole, the first thing to do is to clean the hole out as clean as possible and then run impression block to determine the size and position of the piece. An alligator grab is usually used for taking pieces of steel out of a hole, being operated below a set of jars as explained on page 151.

If you do not have an alligator grab handy, a home-made fishing tool can be made for handling the job. This tool can be made of a piece of pipe about 2 feet long, the diameter of the pipe being such that when the pipe is driven over the piece of steel, the piece will be wedged in the end of pipe.

If the piece of steel is of such peculiar shape that it cannot be wedged in the pipe, the pipe can be split from the bottom upward for a distance of 8 or 10 inches, so that it will conform more or less to the shape of the piece. If the piece of pipe is used, it should be operated on the end of a line of pipe.

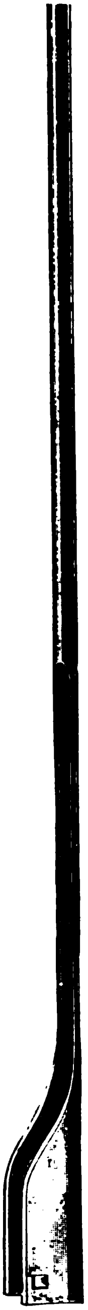
## Something Falls in on Top of Tools Locking the Jars.

It sometimes happens that a piece of rock falls out of the side of bore hole down on top of the tools. It also sometimes happens that something is accidentally dropped into the hole from the top. If the rock or foreign material is of such size that it will not slip down by the side of the tools, the result will be the fastening of the tools above the jars.

As a rule, the piece falling into the hole will lodge on top of the rope socket, or else down along side of the neck of socket, thus locking the jars. As it is hardly ever possible to loosen a string of tools by a straight pull, the first thing necessary to do in a case of this kind, is to try to get the jars to work.

If the substance falling into the hole is a piece of rock, it may be possible to crush it into particles of such small size that they will pass down around the tools.

There are two ways of accomplishing this, one by the use of the bumper, the other by the use of a home-made spud.


Bumper.

The accompanying cut shows the construction and appearance of a bumper, excepting the top end, which is fitted with an eye.

To operate the bumper it is attached to the sand line by passing the end of sand line through the eye. The hitch for fastening sand line through bumper eye is the same as used for fastening line through bailer bail, described on page 16.

After fastening the bumper to sand line, the bumper should be drawn up until it hangs along side of the drill cable, then the cable should be placed between the two outwardly projecting wings on lower end of bumper and a large spike nail passed through the holes in wings. The end of spike should be bent over so that the spike cannot slip out of the holes.

Next take a hard pull on the cable and hold this tension by setting the brake or by throwing in the worm gear. Now lower the bumper into the hole until it rests on top of the rope socket. Inasmuch as the cable has been drawn taut, it is almost as stiff as an iron bar and thus the bumper will slide down over it readily.

To loosen the jars, the tension should be kept in the cable and the bumper elevated to a height of from 10 to 25 feet and allowed to drop onto the top of rope socket. The first blows delivered by the bumper should be from a height of about 10 feet, gradually increasing the amount of drop if no results are obtained. If the tools do not loosen after five or six blows, let slack into the cable until it is loose, but not limber, and again trying the bumper. After three or four blows with the cable slack, try the tools and if they are still tight, put a strain on the cable and again use the bumper. Repeat the above operation three or four times and then if no good is accomplished, the bumper should be removed from the hole, as a further running of the bumper will result in swelling the top of socket to such size that it will have to be reduced before a fishing socket can be used.

After the failure of the bumper, the tool to use is a home-made spud, made as described on page 128 excepting that the blade should be made square across the bottom instead of sharp. The spud should be operated on a line of pipe and should be manipulated as described on page 128, the object being to break the rock into pieces of such size that they will pass the tools.

Inasmuch as the drilling cable is still attached to the tools, great care must be exercised to see that the blade of spud does not strike on top of rope socket as this is very liable to result in chopping off the cable.

If the piece of rock along-side of tools is very hard, such as a piece of granite, or if the spud is being used for driving a piece of iron or some hard foreign substances down past the jars, it may require considerable spudding and thus arrangements should be made for operating the tools by power.

This can be done by attaching the sand line to the end of pipe and then passing the sand line back over the top of spudder sheave. If the sand line is not heavy enough to handle the work, it can be removed from the sand line and a heavier line substituted. In operating the spud, the spudder should be set on the shortest stroke so as not to jam the blade of spud between the tools and the side of hole.

The drilling tools should be tried frequently during spudding operations to see whether or not they are loose.

If you are unable to get results with the above tools it will be necessary to cut the cable at the top of socket so that a heavy spud can be run and so that a fishing socket can be used. Another case which may require the cutting of the cable is when the rock, or whatever has fallen into the hole, is very hard and is of such size that it will not pass down beside the rope socket neck, but lies on top of the socket.

By cutting the rope just above the large obstacle, it makes it possible to remove the obstruction from the hole without the necessity of driving it to the bottom.

If the obstruction is simply a large piece of soft rock it will, of course, not be necessary to cut the rope, as the piece can be easily crushed by using the bumper. If, however, the piece of material is too large to pass down beside the rope socket neck, time can be saved by cutting the rope and then fishing out the obstruction. Also if the obstruction is a large piece of very hard rock, it is probable that time can be saved by cutting the rope and fishing out the rock, for even should you succeed in breaking the rock into fragments of such size that they will pass down beside the socket neck, it will be necessary to drive these pieces down past the jars and this will consume quite a bit of time, besides involving some risk.

Not only will the crushing of the rock cause the fragments to fall down around the tools, but it is also liable to result in cutting the cable, so that not only will the cable be cut but the tools will be wedged as well.

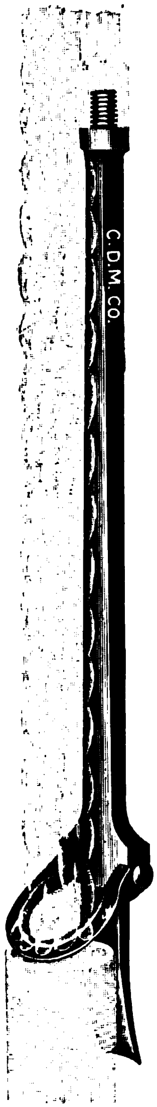
Thus in troubles as outlined above, the driller must size up the situation and then determine whether it is better to first cut the cable, then remove the obstacles, and then fish out the tools, or, second, to crush the rock, then drive the fragments down past the jars and then remove the tools, taking the chance on the last method of having the cable cut in the crushing of the rock.

Of course in either of the above cases when the cable is cut, it is necessary to have a full string of fishing tools consisting of rope socket, set of jars and combination socket and also, if the fishing job is a mean one, an auger stem or sinker bar, and thus your situation in regard to getting the fishing tools needed, must be taken into consideration in figuring on the fishing method to use.

To cut the cable close to top of rope socket or close to obstacle in hole, the tool to use is a horseshoe rope knife. This tool can be operated on the end of a line of pipe but is most easily and quickly handled by the use of the sand line.

The accompanying cut shows the construction of the tool, also the position it occupies when seated on top of the rope socket ready to cut the rope.

In connecting up the rope knife so as to be used on the sand line, the pipe or swivel jars are screwed onto the top of the rope knife and then the sinker rod above the jars, the sand line being fastened through eye of sinker rod.



Horseshoe Rope Knife.

The sinker rod used is the same as illustrated on page 127, and the swivel jars as shown on next page.

The reason for using the pipe or swivel jars instead of the sucker rod jars shown on page 126, is that the sand line has a tendency to twist or turn in the hole and unless some means is provided for taking care of this twisting, the sand line will cause the rope knife to revolve around the drill cable, thus wrapping the sand line around the cable in such a manner that it will interfere with the proper working of the tools.

Pipe or Swivel Jars.

The pipe jars are so constructed that the upper part of jars can revolve without affecting the bottom part and thus the sand line and sinker rod can twist around without moving the rope knife or without wrapping the sand line around the drill cable.

To place the knife around the drill cable, the bolt which holds the blade is withdrawn, the blade is slipped around the cable and then is again fastened to the stem of knife. The knife is so constructed that it will not cut as it is lowered into the hole, but as soon as an attempt is made to lift it, the blade takes hold as shown in cut.

After the knife has been lowered to the point at which it is desired to cut the rope, the line attached to the knife tools should be passed over the spudder and the cable can then be cut by using light up-jar blows.

After cutting the cable, the plan to follow out depends upon the previous conditions in the hole.

If the rope has been cut on account of the inability to loosen the tools by running the bumper and the home-made spud, then the tool to use is either a spud or a spear. If the tools are being held by fragments of rock down along the side, the spud will be sufficient, but if some metallic substance such as a monkey wrench, etc., is down along the tools, it is best to use a spear and drive the obstruction to the bottom.

After removing the obstruction by running the spud or the spear, the tools can be secured by the use of combination socket fitted with slips for catching the top of rope socket.

Instructions for handling the combination socket on a job such as outlined above will be found given under the heading "Cable Breaks."

If the rope has been cut on account of a large rock or other obstacle on top of the tools, then the first thing to do is to try to remove the obstruction. For this purpose an alligator grab can be used as described on page 151 or a home-made friction socket such as described on page 156 can be tried.

If you are able to get hold of the obstruction so that it can be removed, the recovering of the tools becomes a very simple matter, the job being handled as outlined under the heading "Cable Breaks" referred to above.

If, however, you are unable to remove the obstruction and it consists of a piece of rock, it will be necessary to crush it and then drive the fragments down past the rope socket collar with a spud.

If the obstruction is of metal, it will be necessary to use the spear and drive it to the bottom.

In fishing for tools where it has been necessary to use a spud or a spear as just described, it is best to use a heavy stem above the fishing jars, as the tools are liable to be rather hard to start.

## Something Falls in Hole Fastening the Tools Below Jars.

It is very rarely that the tools will become fastened by pieces of rock wedging around them below the jars, unless a hole of considerable size is being drilled, inasmuch as the stem will so nearly fill the hole that rocks of large size cannot enter.

However, when drilling in rock that is much fissured and jointed or in rock or shale which is so soft that it ravels, it sometimes happens that the hole will cave around the stem, fastening the tools very firmly.

As the jars are not locked, a strong effort should be made to drive the tools loose before resorting to the use of fishing tools.

In driving, the jars should be used, not only on the up-stroke, but also on the down-stroke, inasmuch as any motion of the stem either up or down will assist in crushing the rock thus freeing the tools.

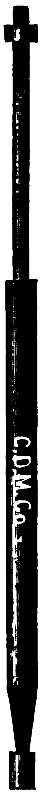
If after three or four hours of steady driving, the tools have not been moved, it will probably be a waste of time to continue further and thus arrangements should be made for running a set of fishing tools.

As it has been proven that the tools are firmly fastened it will be necessary to use a fishing tool which will stand heavy up-driving, also a heavy stem should be used above, and if it is possible to get them, a set of long-stroke jars should be used.

As the drilling cable is still connected to the lost tools, it will first be necessary to cut this off close to top of rope socket. This can be done as described in the previous fishing job.

After removing the cable, a combination socket should be seated on top of the rope socket and the tools driven up with heavy up-jar blows. As you are now driving with a heavy stem above the jars, no trouble should be experienced in loosening the tools. If, however, you are unable to start the tools after four or five hours of steady driving, it will be necessary to break the hold of the fishing socket, remove the fishing tools from the hole and then run a spear down around the tools, after which the fishing socket can be run again.

It is very seldom that it will be necessary to run a spear on a fishing job such as described above, where light water well tools are being used, The reason for using the pipe or swivel jars instead of the sucker rod jars shown on page 126, is that the sand line has a tendency to twist or turn in the hole and unless some means is provided for taking care of this twisting, the sand line will cause the rope knife to revolve around the drill cable, thus wrapping the sand line around the cable in such a manner that it will interfere with the proper working of the tools.



Pipe or Swivel Jars.

The pipe jars are so constructed that the upper part of jars can revolve without affecting the bottom part and thus the sand line and sinker rod can twist around without moving the rope knife or without wrapping the sand line around the drill cable.

To place the knife around the drill cable, the bolt which holds the blade is withdrawn, the blade is slipped around the cable and then is again fastened to the stem of knife. The knife is so constructed that it will not cut as it is lowered into the hole, but as soon as an attempt is made to lift it, the blade takes hold as shown in cut.

After the knife has been lowered to the point at which it is desired to cut the rope, the line attached to the knife tools should be passed over the spudder and the cable can then be cut by using light up-jar blows.

After cutting the cable, the plan to follow out depends upon the previous conditions in the hole.

If the rope has been cut on account of the inability to loosen the tools by running the bumper and the home-made spud, then the tool to use is either a spud or a spear. If the tools are being held by fragments of rock down along the side, the spud will be sufficient, but if some metallic substance such as a monkey wrench, etc., is down along the tools, it is best to use a spear and drive the obstruction to the bottom.

After removing the obstruction by running the spud or the spear, the tools can be secured by the use of combination socket fitted with slips for catching the top of rope socket.

Instructions for handling the combination socket on a job such as outlined above will be found given under the heading "Cable Breaks."

If the rope has been cut on account of a large rock or other obstacle on top of the tools, then the first thing to do is to try to remove the obstruction. For this purpose an alligator grab can be used as described on page 151 or a home-made friction socket such as described on page 156 can be tried.

If you are able to get hold of the obstruction so that it can be removed, the recovering of the tools becomes a very simple matter, the job being handled as outlined under the heading "Cable Breaks" referred to above.

If, however, you are unable to remove the obstruction and it consists of a piece of rock, it will be necessary to crush it and then drive the fragments down past the rope socket collar with a spud.

If the obstruction is of metal, it will be necessary to use the spear and drive it to the bottom.

In fishing for tools where it has been necessary to use a spud or a spear as just described, it is best to use a heavy stem above the fishing jars, as the tools are liable to be rather hard to start.

## Something Falls in Hole Fastening the Tools Below Jars.

It is very rarely that the tools will become fastened by pieces of rock wedging around them below the jars, unless a hole of considerable size is being drilled, inasmuch as the stem will so nearly fill the hole that rocks of large size cannot enter.

However, when drilling in rock that is much fissured and jointed or in rock or shale which is so soft that it ravels, it sometimes happens that the hole will cave around the stem, fastening the tools very firmly.

As the jars are not locked, a strong effort should be made to drive the tools loose before resorting to the use of fishing tools.

In driving, the jars should be used, not only on the up-stroke, but also on the down-stroke, inasmuch as any motion of the stem either up or down will assist in crushing the rock thus freeing the tools.

If after three or four hours of steady driving, the tools have not been moved, it will probably be a waste of time to continue further and thus arrangements should be made for running a set of fishing tools.

As it has been proven that the tools are firmly fastened it will be necessary to use a fishing tool which will stand heavy up-driving, also a heavy stem should be used above, and if it is possible to get them, a set of long-stroke jars should be used.

As the drilling cable is still connected to the lost tools, it will first be necessary to cut this off close to top of rope socket. This can be done as described in the previous fishing job.

After removing the cable, a combination socket should be seated on top of the rope socket and the tools driven up with heavy up-jar blows. As you are now driving with a heavy stem above the jars, no trouble should be experienced in loosening the tools. If, however, you are unable to start the tools after four or five hours of steady driving, it will be necessary to break the hold of the fishing socket, remove the fishing tools from the hole and then run a spear down around the tools, after which the fishing socket can be run again.

It is very seldom that it will be necessary to run a spear on a fishing job such as described above, where light water well tools are being used, and the running of it has been referred to simply to explain what might be done in case of last resort.

## Tools Become Stuck in Bottom of Hole.

The sticking of tools in the bottom of a hole is liable to take place any time during drilling operations, but it is only when the tools become jammed into a crevice or a fresh bit a little over gauge is used, that any serious trouble will arise.

Under ordinary drilling conditions, the sticking of the tools in the bottom does not amount to anything as the tools can be loosened with a few blows from the jars or if the jars are not being used, with a few blows of the bumper.

Even when crevices are encountered or a bit over gauge is used, it is rarely that the tools will become so solidly wedged that they cannot be loosened without resorting to the fishing tools.

If, however, the tools do become so firmly fastened that you are unable to loosen them after four or five hours of up-driving, then the cable should be cut and the plan outlined under "Something Falls in Hole Fastening the Tools Below Jars," should be followed out.

## Tools Become Stuck in the Pipe.

This trouble does not occur frequently and when it does occur, it is usually before the pipe has been seated in the rock. The main cause of tools sticking in the pipe is the presence of gravel or quick sand. The gravel holds the tools by the pebbles becoming wedged between the tools and the inside of pipe. The quick sand causes its trouble by rushing up around the tools with such rapidity that the tools are completely covered before they can be withdrawn from the hole.

We will first consider the trouble caused by the gravel.

As the wedging usually occurs before the pipe is seated in the rock and thus the jars are not on the tools, and as it will be necessary to crush the pebbles in order to loosen the tools, a stiff tension should be put on the cable and the bumper operated as described under "Something Falls in on Top of Tools, Locking the Jars."

If you are unable to get results with the bumper, the cable should be cut at top of rope socket and then a combination socket with long stroke jars and heavy stem above should be run.

If the amount of drive pipe in the hole does not exceed 40 or 50 feet, or if there is a greater amount in the hole and it will pull easily, then it may save time to pull the pipe instead of waiting for fishing tools. Inasmuch as the tools are firmly fastened in the pipe they will, of course, come up with it.

On account of the fact that the drill cable is still fastened to the tools, when the pipe is pulled, a close watch can be kept to see whether or not the tools are coming with the pipe. It may be that the pulling up of the pipe a short ways will result in loosening the tools and thus a careful check should be kept. Even if the tools do not loosen, the bumper should be run after each joint of pipe is removed, as the running of the bumper does not take up much time, and by so doing it may remove the necessity for pulling the full string of pipe.

Care must be exercised during pipe pulling to see that the drill cable does not become slack, as the tools may break loose suddenly and drop back into the hole with such force as to part the cable.

As each piece of pipe, as it is brought to the surface, will have to be removed from the cable, the cable will have to be taken off of the drum, pulled back through the piece of pipe and then re-wound onto the drum. During this operation be very careful to see that no one gets in such a position that the sudden dropping of the tools will permit the cable to catch them, as such a happening may result in broken limbs, or even in loss of life.

The safest plan is to clamp the cable just at top of hole as soon as the joint of pipe has been unscrewed, and for this purpose a pair of clamps as shown on page 42 can be used.

If the tools have become fastened by being completely covered by quick sand, probably the quickest method of recovering them is to pull the pipe as just described, owing to the fact that quick sand packs so firmly that jarring does not have much effect on it.

If, however, there is a long line of drive pipe in the hole, the pulling of which would involve considerable time and risk, it may save time to loosen the tools by running a spear. In using the spear, do not drive it further than the top of the bit, for should it be driven to the bottom of the hole, the quick sand will again rush up around the tools.

By going only to the top of bit, it leaves a plug around the tools which, while it will prevent the inrush of sand, will not be solid enough to prevent the tools from being jarred loose.

To run the spear it will of course be necessary to first cut the cable at the top of rope socket, which can be done as described on page 159.

During the running of the spear, the hole should be bailed from time to time to remove the loosened sand.

After running the spear, a heavy string of fishing tools, as described above should be used.

Besides the troubles caused by gravel and sand, it sometimes happens that the tools will become jammed in a crimped or kinked place in the pipe. When this occurs, the bumper should first be used and if this does no good, then the cable cut and the heavy fishing tools run.

## Gravel Runs in Hole Under Drive Pipe.

When the tools become fastened by gravel running in under the drive pipe, the fishing job involves conditions different from those mentioned in the case just described, owing to the fact that the top of the tools is below the lower end of pipe and thus any attempt to run a string of fishing tools may result in added troubles as the gravel may again run in, thus wedging the fishing tools.

The first tool to try is a bumper, and if the jars are on the lost tools, and they should be, owing to the fact that the drilling is now in rock, it is likely that the jars can be started to work and then the tools driven loose. If, however, the gravel has run in in such amounts that the top of rope socket is covered up, then the bumper will be of no benefit, and it will be necessary to send for a set of fishing tools consisting of horse shoe rope knife and swivel jars, also a rope socket, set fishing jars, a stem, a combination socket and either a spud or a spear.

If the gravel is comparatively coarse, the spud will be of sufficient length, but if the gravel is full of quick sand which will settle the full length of the tools, then it will be necessary to loosen the tools clear to the bottom and for this purpose the spear will be needed.

In handling the job, the first step is to cut off the cable as close as possible to the top of rope socket. After removing the cable from the hole, the pipe should be driven, in an effort to shut off the gravel.

After shutting off the gravel, the spear should be driven down around the tools and after this has been done, the tools can be recovered by use of the combination socket. The combination socket must of course be used below a set of jars with heavy stem above.

It sometimes happens that the gravel cannot be shut off by driving, owing to the fact that the gravel is sifting down through a crevice in the rock.

When this occurs, the gravel can be held in check by cementing the hole around the bottom of pipe and as far down as the crevice extends.

In order to place the cement at the proper point without filling the hole from the bottom, it will be necessary to drive a plug down to the proper point. If the cementing has to be done while the tools are in the hole, a plug should also be placed just above the tools, or if the tools are covered with gravel, on top of the gravel.

Both plugs should be of canvas or burlap, as described on page 154, and inasmuch as the bottom plug is resting on the tools and is not liable to receive much sediment or cuttings, it need not be more than 3 or 4 inches thick.

The top plug, however, should fill the hole for a distance of a foot or more.

Between the two plugs the hole should be filled with water so that the water will serve as a backing for the top plug, thus holding it at the right point until the cement has set.

The cementing mixture should be made up as explained on page 48.

After the cement has set for five or six days it can be drilled out, the plugs removed as described on page 154, and then the hole is in shape to proceed with the fishing job as outlined above.

It is very rarely that a driller is called upon to cement a hole bofore he can use the fishing tools, inasmuch as it is nearly always possible to shut off the gravel by further driving of the pipe. However, when those rare instances do occur, where the gravel keeps slowly falling into the hole, it is best to take the time to put the hole in shape to make the fishing job as safe as possible rather than take chances in the running of the fishing tools.

## Top of Bed Rock Spalls Off.

It sometimes happens that the top of bed rock is very much creviced and shattered as in some granites and schists, also that it is sometimes shelly as certain limestones, slates and shales. When these conditions are met, it may be impossible to drive the pipe far enough into the rock to prevent pieces from falling into the hole.

In case the tools become wedged by a piece of the rock falling down on top of them, the fishing job should be handled by one of the methods outlined under "Something Falls In on Top of the Tools Locking the Jars."

If, however, the rock is of such caving nature that it is unsafe to spend the amount of time in the hole necessary in order to crush the rock and drive it down past the top of the rope socket, then the cable should be cut off at top of rope socket, and the hole cemented throughout the shattered portion as described under "Gravel Runs in Hole Under Drive Pipe." The cement will bind the shattered rock into a solid mass and will thus prevent further caving.

The cementing method just referred to can be profitably used where it is necessary to cement only a portion of the hole but is not to be recommended when large portions of the hole are through caving material. Thus, holes drilled in certain shales will stand quite firm for awhile and then the walls will begin to cave in very rapidly.

Drillers in the oil regions sometimes take chances in such material in an endeavor to get a hole of a certain size down to a firm stratum so that the hole can be cased. Water well drillers also, at times, have to take such chances, where caving strata are encountered between strata of greater firmness. While the writer has repeatedly urged that no unnecessary chances be taken, still there are certain localities where it is necessary for some chances to be taken in order to get a well down at an economical rate.

When a driller knows beforehand that he will have dangerous drilling, he should be provided with fishing tools for taking care of the kind of jobs that are liable to arise in that particular locality.

As a rule it will not require a very extensive fishing equipment as it is only necessary to provide tools for taking care of the fishing troubles which the peculiar formations of that particular section may cause.

If you are operating constantly in such a territory, you should purchase the fishing tools, but if you are going into the territory simply to drill a well or two, it will probably be cheaper for you to rent the tools from your drill manufacturer.

When the tools become fastened in a caving hole, no time should be lost in going after them as each minute lost is liable to add to the difficulty of recovering them.

The bumper should first be run in an effort to start the jars. If the jars can be loosened, the tools can usually be recovered. If you are unable to get the jars to work and the hole continues to cave, then the bumper should be removed and the cable cut off at top of rope socket.

In cutting the cable, the horseshoe knife shown on page 159, should be used and should be operated on the end of a line of pipe instead of on sand line as described on page 160, owing to the fact that if operated on the end of sand line, the caving of the hole may result in fastening the knife.

If pipe is used, the knife can be jarred out even if the hole does cave quite a bit.

In cutting off the rope, it should be cut right at the top of rope socket or not further than 2 or 3 inches from the top as considerable length of rope left standing on top of the socket will interfere with fishing operations.

After cutting the rope, the tools can be recovered by the use of a casing bowl on the end of a line of pipe.

A casing bowl is made very similar to the combination socket bowl shown on page 130, except that the casing bowl is shorter. The top of bowl is made with straight threads the same as combination socket bowl so that the bowl can be screwed onto the end of a piece of pipe or casing.

In fishing with a casing bowl, the bowl is screwed onto the lower end of a line of casing, which is lowered into the hole. Sufficient casing should be used to reach from the top of the lost tools several feet above the surface of the ground.

The size of casing to use depends upon the diameter of the hole in which the tools are lost, but the rule is to use the largest size which will go into the hole, unless the hole is above 7⅝ inches in diameter in which case it is the usual custom to use nothing larger than 6¼ inch casing.

To illustrate what is meant, we will suppose that it is desired to recover a string of tools which are in the bottom of a 5 inch hole. Turning to page 36 it will be seen that the couplings of 4 inch casing are 4.6 inch in diameter and thus 4 inch casing is the largest which can safely be used in a 5 inch hole. Thus, in ordering a casing bowl for the above fishing job, it will be necessary to specify that the bowl is to be used in a 5 inch hole, on the end of a line of 4 inch casing.

After lowering the bowl until it is seated on top of the lost tools, the next step is to set the slips in the bowl. As a rule this is done by lowering the slips on the end of a line of small pipe. As the slips have to be placed between the tools and the inside of casing bowl, it will, of course, be necessary to lower them down on the inside of the casing to which the bowl is attached.

The kind of slips used vary somewhat in shape, but as a usual thing they are shaped somewhat like the slips used in a combination socket being provided, however, with slip bars something like the slip socket slip bars shown on page 135.

Usually three slips are used when the top of rope socket is to be caught and the tops of the slip bars are fastened together so that they can all be lowered and set at the same time. There is another advantage in having the bars fastened together and this is in case it is desired to break the hold of the tools, the slips can be more easily controlled.

In seating the slips, they are shoved down until they come within the taper of the bowl, thus wedging them against the tools.

After the slips have been set, an up strain should be thrown on the pipe in order to make the slips take a firm hold.

After making sure that the slips are firmly fastened an effort should be made to hoist pipe and tools out of the hole.

As it will be necessary to take an extremely heavy pull in order to do any good, arrangement must be made to use pulley blocks. The best way to handle them is to set two shear poles, one on either side of the hole, in a vertical position and then brace the top of poles to the derrick. The top end of poles should not be over 2 feet apart, but the bottom ends should be slightly spread so as to make the poles stand firm. A heavy timber should be placed across the top of poles and should be firmly fastened thereto.

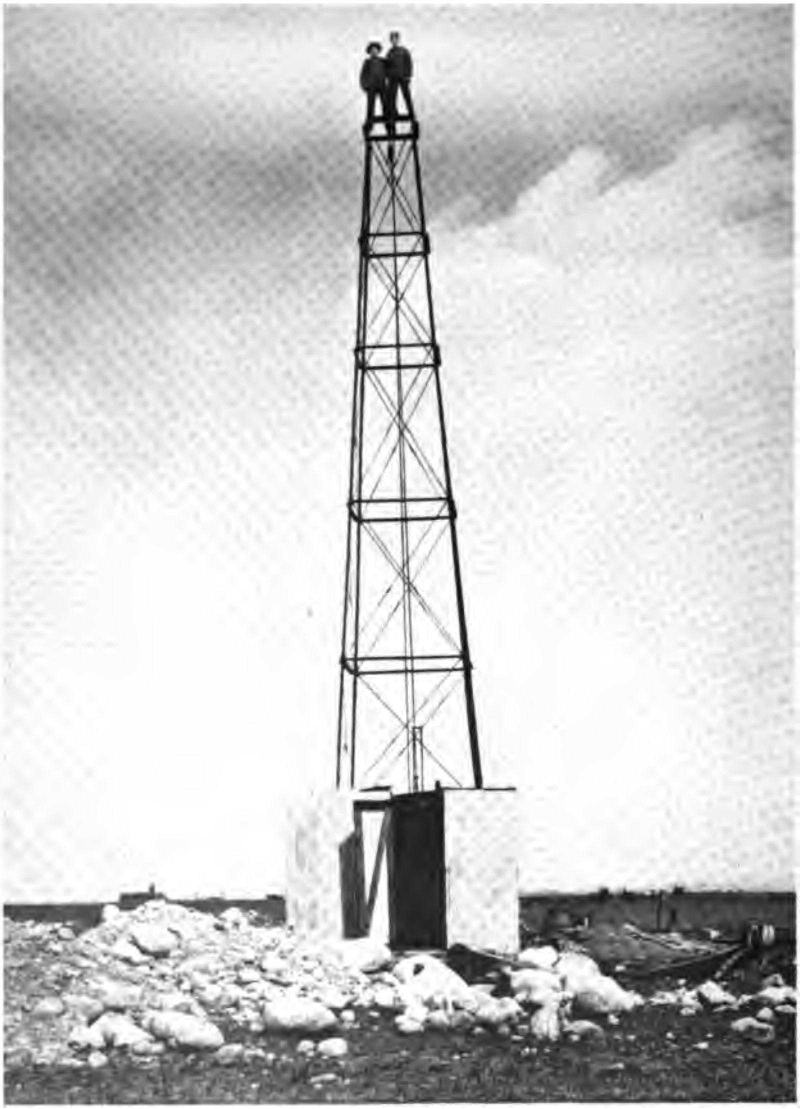
In pulling on the pipe the blocks should be hung from the cross timber at top of shear poles and the fall line should pass from the lower blocks over the crown pulley on top of derrick and then down to the hoisting drum on machine.

The size of blocks to use depends upon the length of pipe in the hole, but it is the usual practice to use triple and quadruple blocks in order to get great hoisting powers.

The shear poles should be 22 to 24 feet long, in order to allow a full length joint of pipe to be hoisted and the bottom ends should be set on good heavy ground sills so that the poles will not tilt.

In order to assist in loosening the tools at the start, a ring and wedge pipe puller is often placed over the pipe and two or more jacks used under this device. You will find this device illustrated and more fully discussed under "Pulling Drive Pipe."

In order to take a sure hold on the pipe when using the blocks, casing elevators are generally used. The elevators are made so as to fit snug



A combination type of drilling machine, capable of handling either Cable, Hollow Rod or Core tools, drilling a deep hole in Montana. Cut shows machine operating the core tools. In order to handle the rods as rapidly as possible the regular derrick has been removed and a special sixty-four foot derrick erected.

around the pipe and in hoisting, the strain comes against the bottom of the pipe coupling. To make the handling of the pipe as rapid and convenient as possible, two elevators should be used. This point will be more thoroughly discussed under the headings "Re-casing a Hole" and "Pulling Casing."

After the tools start upward, their recovery means simply the pulling of the pipe, which should be handled as explained under "Pulling Casing."

If you are unable to start the tools by the use of the blocks, assisted by jacks placed under the ring and wedge puller, then the blocks should be slacked off, first, however, tightening up the jacks so that all of the strain will be taken up by the jacks. Now remove the blocks from the shear poles and also the fall line should be taken off of the drum of machine and the blocks and line laid to one side. Next remove the cross timber from the top of the shear poles. Arrangements should now be made for driving up on the pipe. This can be done by the use of one of the pipe pulling devices described under "Pulling Drive Pipe."

If there is a long line of pipe above the casing bowl, it will probably be necessary to use a very heavy drive weight, but even on the most stubborn job, the driver should not exceed 1500 pounds in weight, owing to the fact that the blow delivered by a very heavy driver is liable to strip the threads on the pipe.

By using the driver in connection with the ring and wedge pulling device, the tools should be loosened, or at least the jars should be loosened. After the jars are loose, the pipe should be jacked up until the jars are fully extended and then the driver again called into play.

If the hole is not over two or three hundred feet in depth and you are able to get the jars to working then the top of the pipe can be fastened directly onto the drilling cable and the tools can be driven loose by placing the cable on the spudder and driving up with the full weight of the pipe.

If you are able to start the tools by the use of the ring and wedge and the driver, then the blocks can be rigged up again and the pipe, with tools, can be hoisted out of the hole.

If you are unable to start the tools by any of the methods advocated above, then the only thing left to do is to ream the hole down to the top of the lost tools, set in a line of casing and then proceed to loosen the tools by running a spear, after which they can be recovered by the use of appropriate fishing tools.

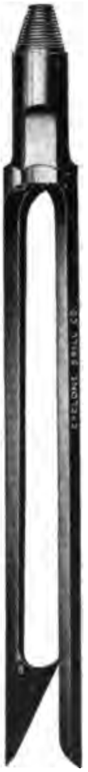
Before beginning a reaming job, however, you should first carefully consider whether or not the reaming is an economical proposition. This point you will find discussed on page 154.

If you decide that it will be an economical proposition to ream the hole, then the job should be handled as described on pages 154 and 155.

## Bailer Becomes Lost in Hole.

If the bailer becomes lost due to the parting of the sand line and there remains in the hole quite a bit of the parted line, it may be possible to recover the bailer by the use of a rope spear as shown on page 123.

If a rope spear such as referred to is not available, a home-made tool can be used. This home-made tool can be constructed on the order of a rope knife shown on page 125 excepting that the edges of the hook should not be sharpened and the bottom of slot should be drawn in close so that in case the sand line is caught in the slot it will be securely wedged therein. The tool should be operated on the end of a line of pipe.



Bailer Grab.

If but a few feet of line are left above the bailer it will hardly be possible to recover the bailer by catching the line and thus a tool for catching the bail of bailer must be used.

If the hole is not very deep the bail can often be caught by making a hook on the end of a line of pipe and lowering it into the hole. If however, the hole is so deep that the pipe cannot be used or if the bailer is so firmly fastened that it cannot be loosened by the pipe tools, then it will be necessary to use a regular bailer grab.

The accompanying cut shows the construction of this tool.

To use the tool, it is placed below a set of jars, the bailer being caught by passing the hook of the grab under the bailer bail.

In jarring up on a bailer when it has been caught by the bail, the blows must not be severe as heavy blows are liable to shear the rivets holding the bail to the shell.

If the bailer has become lost due to the bail pulling loose from the shell, then it will be necessary either to go down on the inside of the bailer with a casing spear or go on the outside with some form of fishing socket.

If the bailer is not fastened in the hole, it may be possible to recover it with a horn socket or a long friction socket. If securely fastened, a slip socket or a collar grab socket should be used.

If the bailer is securely fastened and is of such size that it is impossible to get a slip socket or collar grab socket around it, then it will be necessary to go down on the inside with a casing spear, description of which is given further over under "Pulling Casing."

If none of the above methods are successful, then the bailer can be drilled out of the hole. This method, however, should be considered a method of last resort as it is usually a time consuming proposition.

To drill up a bailer the drill bit should be dressed much sharper than in rock drilling, the angle between the bit faces being between 45 and 60 degrees. After running the tools on the bailer for some time, the top of bailer will be stoved over and so battered that it will completely fill the hole. When this point is reached, the tools should be withdrawn from the hole, and if possible, all of the water bailed out.

Now dump four or five gallons of very stiff clay in the hole. If you are unable to bail out the water down within 2 or 3 feet of the top of the lost bailer, then 10 or 15 pounds of putty should first be put in the hole and then the clay dumped in.

The clay and putty are for the purpose of holding the chopped up iron off the top of the bailer as otherwise the heavy iron flakes will settle down on top of the bailer, thus preventing the bit from doing any cutting.

The hole should be bailed out from time to time and fresh supplies of putty and clay should be put in.

In bailing out, a vacuum pump as shown on page 17, is of great assistance as it will lift all of the heavy cuttings off of the bottom.

When the bailer has been drilled out down as far as the valve, it may be necessary to use a bit with a flatter cutting edge in order to prevent the bit from glancing and drifting.

However, the thin bit should be used all the way through if possible, owing to its more rapid work.

The time required to cut up a bailer depends, of course,, upon the size of the bailer, but on a correctly handled job, a 4 inch by 10 foot bailer should be gotten rid of in about 20 hours steady drilling.

## Something Falls In on Top of Bailer.

If a bailer is fastened by small particles down along the side, it can sometimes be loosened by light, jerking blows on the sand line.

If it is fastened by an obstacle of too great size to pass down along the side of the bailer, the use of light, jerking blows will tend to jostle the obstruction into the bailer. Thus, the first thing to do when the bailer becomes fastened is to attempt to loosen it by jerking on the sand line.

To jerk the line, the engine should first be speeded up, then 5 or 6 inches of slack let in the line and then the sand reel friction thrown lightly against the power.

Do not let much slack in the line and do not throw the friction in hard, as the sand line may be parted.

If, after jerking the line 15 or 20 minutes and no results are obtained, a pretty stiff pull should be taken on the line and the tension held in the line by throwing the friction against the brake.

Next run a home-made spud, as described on pages 128 and 129, down around the bailer.

If the bailer is wedged along the sides, the spud will crush the obstacles or else drive them to the bottom, and if it is fastened on top, the spud will crowd the piece into the bailer. By watching the sand line, it can be told when the bailer comes loose.

If you are unable to get results with the home-made tool, it will be necessary to cut the sand line at top of bailer, and then run the heavier spud as shown on page 129.

If you are using a small wire line for sand line, it can usually be cut by use of a home-made knife on the end of a line of pipe, as described on page 127. If the hole is too deep or the wire line is too big for handling with such tools, then it will be necessary to use a regular wire line cutting tool.

Probably the most satisfactory tool for this purpose is known as Mape's patent wire rope knife, which is operated on the end of sand line or on end of pipe or sucker rods.

After cutting the line and running the heavy spud, the bailer can be caught with a horn socket, a long friction socket, a slip socket or a collar socket.

## Valve Pulls Out of Bailer.

This fishing job cannot, of course, prove serious, but it is sometimes very annoying, owing to the difficulty experienced in getting hold of the lost piece.

If you do not have an alligator grab handy, it will be necessary to make a tool for the purpose. The kind of tool to make depends largely upon how the piece is lying in the hole. If it is lying on its side, it will be necessary to use some sort of a grabbing device, but if it is standing anyways near straight, it may be possible to wedge it into a tool made somewhat on the order of a horn socket.

If a tool made on the order of a horn socket is used, its efficiency can be increased by packing it full of stiff, plastic clay, which will assist in holding the piece.

A grabbing device can be made by splitting a piece of 2½ or 3 inch pipe and notching the split edges so that the edges will take a firm hold when seated over the lost piece.

Both of the home-made tools described above can best be used on the end of a line of pipe.

If such a thing should happen that you are unable to recover the bailer valve, it can be gotten rid of by shooting it into the side of the hole. To do this several pounds of dynamite should be placed at the bottom of hole and then fired. The amount of dynamite to be used depends upon the kind of material at the bottom of hole.

If the material is soft shale, medium hard sand rock or soft limestone, two or three pounds should be sufficient. If, however, the hole is in hard rock, it may require 10 to 25 pounds.

After firing the shot, the tools should be lowered to determine the condition of the hole. If the valve cannot be felt and the hole does not have to be drilled more than 10 or 15 feet deeper, then it will be all right to go ahead with the drilling.

If, however, the hole will have to be continued on down to a depth which will bring the top of tools below the point of shooting, it will be safer to cement the hole at the point shot. The cementing of the hole will prevent the valve from rolling in on top of the tools and will also eliminate all chance of the shattered wall from spalling off.

If the hole can be bailed dry, the cementing can be easily done as the cement can be poured in from the top. If, however, the hole makes water, the cement should be lowered by using a dart valve bailer or else by forcing it down through a line of pipe.

The advantage of using the bailer or pipe is that the cement is placed at the very bottom of the hole without having to pass through the water which would wash nearly all of the strength out of it.

The amount of cement required will depend upon the size of opening at the bottom. Enough should be used to completely fill the opening and allow the cement to stand 1 or 2 feet up in the round part of hole.

After the cement has set fairly hard, the work can be resumed and the hole continued on down without fear of caving trouble from the blasted part of hole.

The blasting method of removing the bailer valve referred to above can sometimes be used for getting rid of other troublesome small pieces lost in a well.

## Fishing Socket Bowls.

As a usual thing a well driller is called upon to drill holes of different sizes. Thus, while the standard size of wells in certain localities for domestic purposes may be 5½ inches in diameter, the factory wells and wells to be pumped for large capacity may be 6, 8 or even 10 inches in diameter.

In the large majority of cases, the drillers use the same size string of tools for handling the different sizes of holes, the only changes made being in the size of bits used.

In order to make it possible to use the same size of fishing tool in the different sizes of holes, the fishing sockets are provided with extra bowls of different sizes, these extra bowls being so arranged that they can be fastened onto the bottom of the regular socket bowl. Thus, if 5½ inches is the diameter of the smallest hole drilled, the fishing socket is made for a 5½ inch hole and then if it is desired to use the socket in larger holes, bowls of the proper sizes are supplied.

The advantage of having a large bowl on a small socket, when the small socket is to be used in a large hole, is that the extra bowl will guide the top of lost tools into the main bowl of fishing socket, thus eliminating the necessity of fishing around for the top of the lost tools.

Extra bowls can be furnished with all fishing tools which operate by catching around the lost tool, these sockets being horn sockets, long friction sockets, collar sockets, slip sockets, etc.

## Breaking the Hold of Fishing Tools.

There are two general types of fishing tools—those which take a friction hold and those which depend upon slips.

Under the friction sockets are included horn socket, long friction socket, collar grab socket and short friction socket.

Under the sockets which use slips are included slip socket, combination socket, pin socket, collar socket, casing spears and the several types of jar sockets.

As it sometimes happens that the lost tools are so firmly fastened that it is impossible to loosen them, it is necessary to loosen the hold of the fishing tools in order to recover the fishing tools.

When the friction type of fishing socket is used it can be loosened by hard up-driving.

With the sockets using slips it is necessary to first break the slips. This can be done by so adjusting the slack in cable that the jars strike on both the up and down stroke.

If short stroke jars are used, it often requires considerable time to break the hold, but if regular long stroke fishing jars are used and the crank pin set out in the last hole, it does not take much hammering to bring results.

What has been said above refers to loosening the fishing tools when the tools are down in the hole. It is also necessary to know how to loosen the fishing tools from the drilling tools after the drilling tools have been removed from the hole.

A horn socket or a collar grab socket can be loosened by driving a wedge into the slot along the bowl, the wedge expanding the bowl a sufficient amount to allow the tools to be jarred loose.

When a long friction socket has been used it is necessary to drive it off of the tool. To do this a tool wrench, or better still, a pair of drive clamps should be placed on the square on the recovered tool below the friction socket and then the socket driven off with the spudder.

To loosen a combination socket used to catch a rope socket neck, the rope socket should first be unscrewed from the drilling tools, and then the combination socket bowl unscrewed from the pin end of socket. By unscrewing the bowl the spring and spring plate can be removed after which the slips can be loosened by turning the socket upside down and then jarring it lightly by bumping it up and down on a piece of wood.

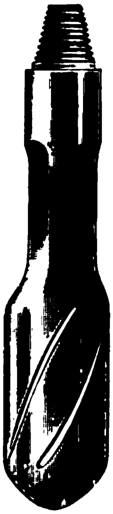
To loosen a combination socket when it has been used to catch a pin, the procedure is the same excepting when the pin of a stem has been caught, in which case it is not feasible to turn the stem upside down and thus, after disconnecting the socket bowl, the bowl should be jarred down as far as possible, when the slips can be pulled loose.

To loosen a slip socket, the socket should be driven down. This will result in taking the pressure off of the slips so that they can be removed. After removing the slips, the socket can be driven up and off the tool.

For removing the other types of sockets such as the various types of jar sockets, etc., the methods to follow are practically the same as above.

## Taking Kinks and Crooks Out of Pipe.

Drive pipe is sometimes kinked on the end by driving it onto a boulder. It is also at times crimped in at the lower end by driving it into the bed rock. Other troubles may be caused by driving the pipe along a slanting boulder which will result in slightly springing the pipe out of line. Also there may be blisters or bumps on the inside of pipe which will interfere with the proper working of the tools, or the recasing of the hole.



Pipe Swage.

In handling the above troubles a tool called a pipe swage is used.

To use a swage for driving out kinks, for straightening out a smashed end or for driving out blisters and bumps, the swage is placed below a set of jars with the stem above.

For straightening a piece of pipe, the swage is used below a stem with a set of jars above the stem and a heavier stem above the jars.

If the pipe has been kinked in at the end, due to driving onto a boulder, the pipe should be pulled back from the boulder before the swage is run.

If the end of pipe has been crimped in or smashed in, due to driving the pipe into the bed rock, the pipe should be withdrawn a foot or two above the rock before running the swage.

If a piece of pipe is to be straightened, the pipe should be drawn back from the obstruction causing the trouble.

A swage used for pipe straightening is generally three or four times as long as the other type of swage, the extra length being provided in order to take the strain off of the pin and off the stem.

You will note from the cut that the body of swage is fluted, the flutes being used so that in case there is water in the hole, the water can pass upward as the swage is driven down.

It sometimes happens that the end of pipe becomes smashed in while the bottom of the line of pipe is in sand which runs several feet up in the pipe, thus preventing the running of the swage. Under such conditions, it is necessary to pull the pipe back to a point where the bottom of the pipe can be opened up without the sand rushing in.

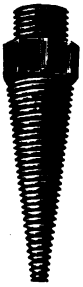
## Recovering Pump Pipe Lost in Hole.

Pump pipe fishing jobs are usually due to either one of two causes, namely, the pipe is accidentally dropped into the well or else the pipe becomes rusted out and parts when an attempt is made to recover it.

For pipe ranging in diameter from 1 to 2 or 2½ inches or for pipe up to 4 inches in diameter when the amount in the hole does not exceed 150 or 200 feet, a taper tap will prove satisfactory, if the hole in which the pipe is lost is not over 1½ inches larger in diameter than the outside diameter of the coupling used on the pump pipe.

The reason for limiting the size of hole in which the taper tap is to be used is that it is a troublesome proposition to locate the end of a pipe of small diameter in a hole of large size.

To use the taper tap it is lowered into the hole on the end of a line of pipe or sucker rods aud after it has been seated in the end of the pipe, the rods are turned to the right (unless a special left hand tap is being used) so as to give the threads on the tap a chance to take hold.



Taper Tap.

If the top of pump pipe is provided with a coupling, the threads will screw into the coupling, but if no coupling is present the tap will cut threads on the inside of pipe so that a firm hold will be secured.

If the pump pipe is greatly rusted so that the walls are not thick enough to give a taper tap a firm hold, then it will be necessary to use a taper socket, which is a tool made with an inwardly tapering bowl which bowl is threaded the same as taper tap.

The advantage of taper socket over the taper tap when fishing for rusted pipe is that the bowl will not cause the pipe to spread.

The taper socket is used on the end of a line of pipe the same as the taper tap.

The taper socket can be used for fishing for pump pipe of small diameter in a large hole if the socket is provided with a fishing socket bowl as described on page 173.

When only a short length of pipe, say 100 to 150 feet, is in the hole, and when the pipe is not over two inches in diameter, it can often be recovered by the use of a regular horn socket, as shown on page 136.

To fit the horn socket for this work, a block of wood should be driven up into the socket bowl, the wood being of such length and diameter that when driven up as far as it will go, the lower end of block comes about 8 inches from the lower end of bowl. The wood used should be soft pine and before being driven into the bowl should be ripped down through the lower end for a distance of 6 to 8 inches by taking two or three cuts with a saw.

To operate the socket, it should be placed below a set of jars and then lowered into the hole until it rests upon the pump pipe. Now drive down with the jars, using light blows, and the pipe will be driven into the split end of the wood which will hold it securely.

Besides the tools described above, there are other types of pipe fishing tools, these being known as casing spears, mandrel or bell socket, tubing spears, tubing spears with socket, combination tubing socket, friction socket, and casing dogs.

All of these tools can be used either in connection with cable tools or on the end of a line of pipe, but as the principle of their action is practically the same as the fishing tools described under "Part IV," we will not go into the matter further.

Before leaving the present subject, the writer desires to refer to one kind of pump pipe fishing job which sometimes arises which is somewhat different from the ordinary job, this being the recovering of pump pipe where the pump rod is in the pipe and extends some distance above the upper end of the pipe.

This kind of a job is best handled by the use of a taper socket as previously described except that the socket should have a hole drilled from the top of the pin down into the bowl. The hole should be so drilled that it comes in at the very top of the bowl so that when the socket is lowered into the hole the pump rod will pass into the socket and on up through the hole, thus permitting the bowl to be seated on top of the pipe.

The hole through the bowl should be of ample size to allow the pump rod to pass, and the joint of pipe immediately above the taper socket should be at least two feet longer than the length of pump rod sticking out above the pump pipe.

## Straightening a Hole.

The straightening of a hole in hard rock has been discussed under granite drilling on pages 61 and 62 and the writer would therefore refer you to these pages.

As stated under granite drilling, the only remedies proving efficient in straightening crooked holes in hard rock formations are the use of iron and steel, and shooting.

However, in the softer formations there are various methods and classes of tools which will prove effective.

One of the most common methods is to drive to the bottom of the hole a piece of timber of such diameter that it just about fills the hole and of such length that it comes up past the crook. If the crook is several feet above the bottom of the hole, the piece is made with a diameter which will just allow of its being driven into the hole so that it will "hang up" at the crook.

After seating the piece of timber at the proper point, the drilling tools are put in and the piece drilled out. In drilling out the piece, the tools should be run on a tight cable and the bit should be dressed rather blunt and with full wearing surface.

The above method proves very satisfactory in medium hard formations and is a method that can be applied without resorting to special tools, as the only thing needed is a piece of timber, which can be cut almost anywhere, and the regular drilling tools. If you are drilling in a region where you cannot get the timber, then pieces of crushed rock or hard pebbles can be used.

Round Reamer.

The idea of using either the timber or the crushed rock is to hold the bit at one point a sufficient length of time to enable it to start a shoulder, or as drillers say "eat into the crook."

A reamer will greatly assist in taking hold of the crook as the reamer has a blunt edge and the blade is made of sufficient width and thickness to almost fill the hole. A Mother Hubbard Bit dressed blunt will also prove more effective than an ordinary taper shank bit for the same reason. The use of a star bit is also often effective in straightening up a hole.

Mother Hubbard Bit.

Besides the above tools there are various other devices used, among the most important of them being Kearne's hole straightening bit and Mack's patent hole straightener.

The Kearne's bit is made very full around the shank and the blade is of such size and so shaped that the cutting edge, which is slightly beveled inward, is forced against the walls of the hole.

Mack's patent hole straightener consists of collars 10 to 12 inches long with a threaded hole through them, the hole being of such diameter that the collars can be slipped onto the stem over the joint collars. The straightening collars are placed at different points along the stem, it being the usual practice to use 2 or 3 of them on a stem 20 feet in length.

To hold the collars firmly to the stem, threaded slips are placed between the collars and the stem and then the collars are screwed onto the slips, which as they are made on a taper are thus made to seize the stem.

As the outside diameter of the straightening collars is such as to just fill the hole, the stem is prevented from being thrown out of line and thus the edge of bit or reamer is held against the crook.

Inasmuch as the use of the collars throws a heavy side strain on the bottom joint, a stiff tension should be kept on the cable in order to prevent the tools from jamming against the crook with such force as to snap the pin on the bit.

As stated under "Drill Bits" page 104, it is necessary to have bits of proper proportion in order to keep the hole straight and while this is true in all classes of drilling, it is especially true when drilling in hard formations which lie at an angle or which are greatly shattered.

If most of your drilling is to be in difficult formations such as just referred to, it is best to have very thick bits, as the thick bits will not only assist in holding the hole straight, but they will serve as a protection to the pin of the bit which has to stand up under heavy strains when slanting strata are struck or slanting crevices are encountered, these strains being so great as to be dangerous unless the blade is of sufficient thickness, width and length to protect the pin.

## Reaming a Hole.

What is ordinarily meant by reaming a hole is the enlarging of a hole already drilled.

As a rule, reaming is for the purpose of increasing the size of a hole so that casing can be set or for the purpose of enlarging a hole so that fishing tools can be run.

For such reaming, an ordinary round reamer as shown on page 178 is generally used. Besides a round reamer, a Mother Hubbard type of rock bit, dressed very flat is often used.

When reaming, a stiff tension should be kept on the drilling cable unless the rock being reamed is of such nature that the tools stick badly, in which case sufficient slack should be let in the cable to allow the jars to work and the tools should be run at a slower rate.

What has been said above refers to an ordinary reaming case.

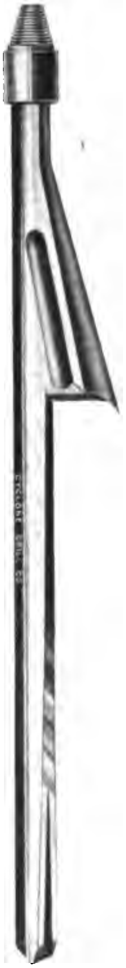
Besides the above, there are special reaming cases where it is desired to ream or enlarge the hole below the drive pipe or casing so that the pipe can follow. This kind of reaming is generally done in those regions where caving material is encountered after the bed rock is struck.

For handling this kind of work two general types of tools are used, these being known as enlarging bits and under-reamers.

An enlarging bit is made with a side wing projecting on one side, the bit being so proportioned that when drilling the side wing is forced out under the pipe thus enlarging the hole. This action is brought about by making the center line of lower bit blade in line with the center line of stem on which it is used.

While the entire width of the enlarging bit is not greater than the diameter of the pipe through which it is used, still, owing to the fact that the lower blade comes in line with the stem, the tendency of the lower cutting edge is to cut straight ahead and this action compels the cutting edge of wing to be forced into the wall.

In dressing an enlarging bit the corner of cutting edge, of lower blade, opposite the enlarging wing should be dressed rounding as this will assist in forcing the wing into the wall.



McCleary's Enlarging Bit.

An enlarging bit proves very satisfactory for enlarging holes in shale or rock of medium hardness but is not to be recommended for enlarging holes in hard rock. The accompanying cut shows the construction of a McCleary's enlarging bit and the cut on the following page shows the method generally used for holding the pipe which is intended to follow after an enlarging bit.

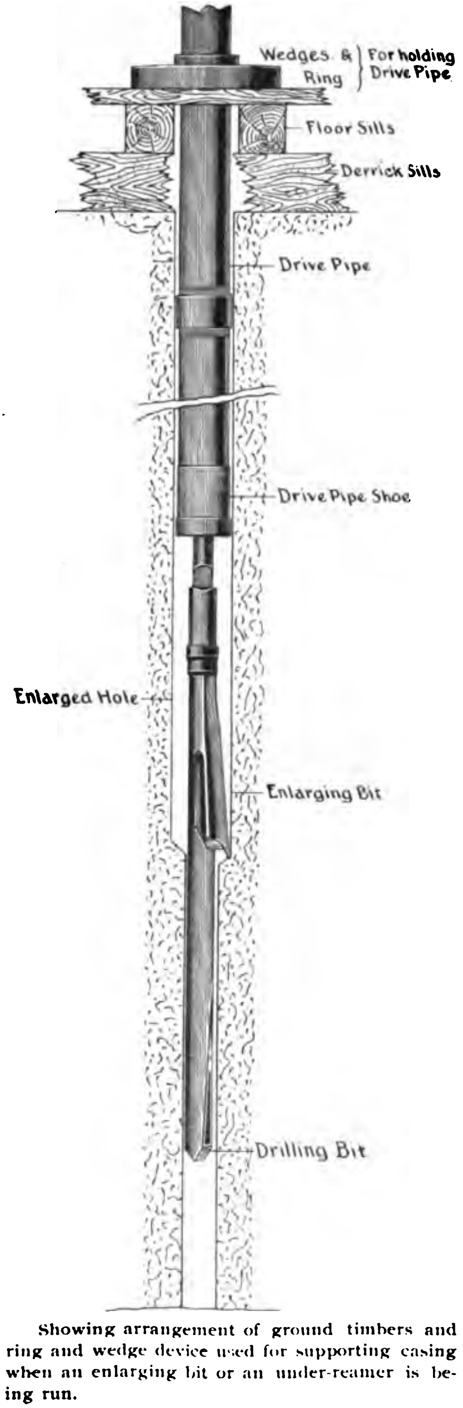
As an enlarging bit is generally 3½ to 4 feet long, it is necessary that the bottom of the pipe does not come within 6 or 7 feet of the bottom of the hole. This is for the purpose of giving the wing a chance to eat back into the walls.

To get any results with an enlarging bit it is necessary that the hole be enlarged at the same time that it is being drilled, for the reason that the total width of the bit, as stated above, does not exceed the internal diameter of the pipe through which it is used. Thus an enlarging bit which would just go into a 6 inch pipe and which would, when properly used, be capable of enlarging the hole to 7½ inches, would be of absolutely no benefit if used in a 6 inch hole which had already been drilled.

There is, however, one exception to the above and that is when the hole extending below the end of the pipe is quite a bit smaller than the internal diameter of the pipe. Thus, if the hole below 6 inch pipe is but 3 inches in diameter then the lower blade of enlarging bit will be compelled to enter the small hole and this will result in forcing the enlarging wing out into the walls. This plan is sometimes followed when it is hard to get the enlarging bit properly started.

The enlarging bit as stated above, is a very effective tool for medium hard material, and where conditions are right for its operation, its use is to be recommended owing to its comparative cheapness, also owing to its simplicity. However, for hard rock work, an under-reaming bit is much more satisfactory.

Another advantage of a regular under-reamer is that it can be used for enlarging a hole that has already been drilled. Thus if a line of 6 inch



Showing arrangement of ground timbers and ring and wedge device used for supporting casing when an enlarging bit or an under-reamer is being run.

casing has been set and a 6 inch hole has been drilled on down below and it is desired to set the 6 in. casing on down, all that is necessasary is to hoist the casing 3 to 4 feet off the bottom and then run the under-reamer.

The cut on page 182 shows the construction of one of the best types of under-reamers, also shows the action of the tools when in use.

In the cut shown, a regular rock bit is attached to the lower part of reamer and the hole is being reamed at the same time that it is being drilled. This is the usual way of using the reamer, but as stated, it can also be used for enlarging a hole already drilled.

As under-reamers must be made very substantial in order to stand the heavy strains thrown upon them and as they also involve a large amount of careful and accurate machine work they must of necessity sell for a pretty high figure and thus, while they are very handy tools to have, they are not very generally used for well drilling purposes.

## Pulling Drive Pipe.

There are three general methods of pulling drive pipe, namely:

Pulling with Jacks,
Pulling with Pry Pole, and
Pulling with Pipe Jar Devices.

Besides the three individual methods named, the methods are often combined, that is, one of the methods may be used in combination with either of the others. In order not to get matters mixed the methods will be taken up separately.

## Pulling with Jacks.

Austrian Under Reamer.

In pulling with jacks it is necessary to fasten some sort of clamping device around the pipe, the device being of such size and construction that jacks can be placed under the clamp and worked against it.

On short lines of drive pipe or on pipe that does not pull extremely hard, the clamps can be made of wood and can be constructed the same as those shown on page 42. Even on extremely heavy pulls the wood clamps will prove satisfactory if two sets of clamps are used, one being placed immediately above the other and at right angles to it. By placing the clamps at right angles it is possible to use four jacks, one under each end of the clamps.

If the clamps have a tendency to slip on the pipe, even after the bolts have been drawn up as tight as possible, they can be made to hold more firmly by placing pieces of old files or rasps between the pipe and the rounding part of clamps and then drawing up the clamps as tight as possible.

Any style of jacks can be used under the clamps, but for a difficult job, requiring a steady, hard pull, screw jacks or hydraulic jacks are to be preferred. Lever jacks can be used if they are handled so that all of them are operated at one time, but owing to the fact that one notch on a lever jack elevates the head about one-half inch, the working of one jack at a time will tend to loosen the clamp, inasmuch as it see-saws the clamps up and down. While a very steady pressure can be applied with screw jacks, nevertheless, owing to the labor required to operate this type of jack, its use is not to be recommended on extremely heavy jobs requiring the pulling of a considerable length of pipe, unless it is impossible to secure hydraulic jacks.

The hydraulic jack is ideally adapted for pipe pulling jobs as with it enormous loads can be lifted with comparatively slight effort on the part of the operator. Another advantage of the hydraulic jack is that its action can be very closely controlled and thus a very steady pressure can be applied.

When pulling pipe requiring a very heavy pressure to move it, the ring and wedge pulling device is to be preferred to the clamps mentioned above. This device consists of a heavy cast steel or cast iron frame through the center of which passes a hole 3 to 6 inches larger in diameter than the pipe over which it is to be used. The hole is beveled, the large part of bevel being at the top. Slips or wedges with bevels corresponding to the bevel in the block are furnished.

Ring and Wedge Pipe Puller.

In operating the ring and wedge device, it is placed over the pipe and lowered until it rests upon the jacks. The slips should now be placed and a sufficient pressure exerted from below to make the slips take hold. In using the device, care must be exercised to see that the jacks are brought up evenly as a heavy side strain resulting from uneven pressure may cause the slips to snap.

By equipping the ring with slips of different sizes, the same ring can be used for handling two or three different sizes of pipe.

## Pulling with Pry Pole.

Unless the amount of pipe to be pulled is small, it is very seldom that a pry pole is used. Where, however, the conditions are favorable for it, it proves a fairly rapid manner of getting pipe out of the ground. As a usual thing, the pry pole is used in connection with the pipe-jar devices.

To rig up a pry pole, or as drillers usually call it, a "monkey pole," secure a heavy piece of timber 25 to 30 feet long, and 12 to 14 inches square. If a square timber cannot be obtained, use a round one. A telephone pole 14 to 16 inches in diameter at the big end and 25 to 30 feet long will prove satisfactory.

To use the pole, place the large end against the pipe to be pulled, and allow the pole to extend outward from the pipe in line with the machine. The reason for extending the pole in line with the machine is that by doing this, the pole can be handled with the sand line.

Next fasten the sand line to the outer end of the pole and then by throwing the sand reel in gear, elevate the outer end about 10 to 12 feet from the ground. In doing this one man should steady the pole so that it does not swing around side ways. After elevating the pole, the proper distance, hold it in this position and then slip a piece of timber crosswise under it up next to the lower end of the pole, to fulcrum over. A heavy railroad tie makes a good fulcrum timber. This piece of timber should be placed as close up as possible in order to give the greatest prying power to the pole. Now wrap a good heavy log chain around the pipe and bring the ends of chain up over the end of pole, next to pipe, and hook them.

You are now ready to slack off the sand line and let the weight of the pole come upon the pipe.

To increase the lifting effect, one or more men should walk out on the pole and spring up and down on it. In doing this, be sure and stand, not sit, on the pole for the reason that something might give way at the lower end and if you are sitting, your legs will be below the pole and may be caught.

When the lifting of the pipe allows the outer end of pole to touch the ground, it can be elevated again by use of the sand line as described above.

Some drillers in using a pry-pole, cut a rounding notch in the lower end of the pole, so shaping the notch that the end of pole will straddle the pipe. As this will prevent the end of the pole from slipping off the pipe, it is quite an advantage. The work can also be made easier to handle by digging a hole about 2 feet square and 1 foot deep around the pipe, as this will allow the chain to be more readily adjusted.

## Pulling with Pipe Jar Devices.

Under certain conditions of pipe pulling, a blow is much more effective than a straight pull. In those cases where the pulling of the pipe means simply the lifting of a certain weight, as in lifting unconfined casing out of a hole, any arrangement which will permit of a strong, steady pull will prove efficient. However, in the pulling of drive pipe, owing to the fact that the pipe is firmly held by the enclosing ground, a straight pull, unless of enormous extent, will not do much good. As it is impracticable in the large majority of cases to rig up apparatus of sufficient power to move a line of drive pipe by direct pull, drillers resort to the principle stated above, namely, a blow is more effective than a pull.

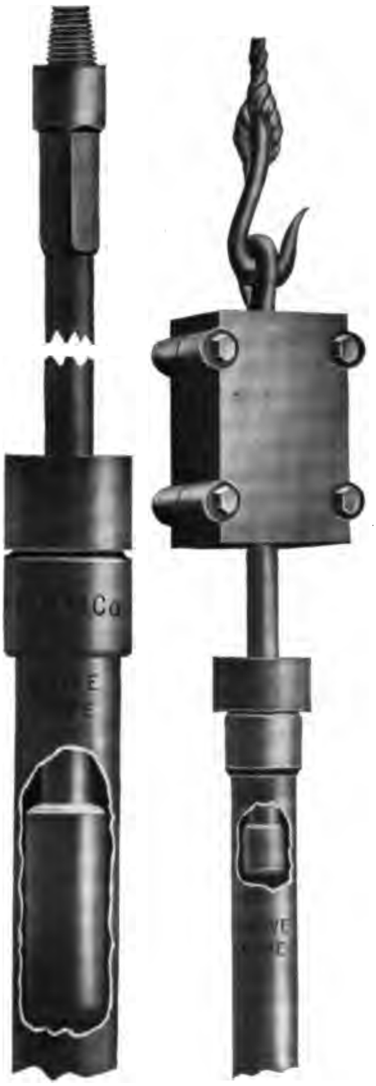
The cut on next page shows the construction of two different types of pipe jar devices for pulling drive pipe.

The pipe puller on the left is for use with cable tools and the one on the right for hollow rod tools. However, the hollow rod device can be used in connection with cable tools by screwing into the rope socket of the cable tools a pin hook as shown on page 120.

Where very hard driving will be required, the rod type of driver is to be preferred inasmuch as the weight of the driver can be increased any reasonable amount by bolting on more sections. However, even on the most stubborn jobs the weight should not be greater than 1200 to 1500 pounds. The size of the weight used on ordinary jobs ranges from 300 to 500 pounds.

Considering one of the driving devices in detail, it is made up of the following parts—stem, jarring head, drive weight and pulling plug. On the cable device, the stem is made heavy enough to furnish the weight, except on some special jobs a regular auger stem is screwed onto the top of the driver stem. As the addition of the auger stem gives quite a length to the tools, its use is not practicable unless the pipe has to be elevated only a short distance or unless the drive pipe is in short lengths.

Of course, if the derrick is of sufficient height the adding on of the auger stem makes no difference, but derricks as ordinarily furnished on portable rigs will not be of sufficient height to admit of pulling full length pipe when an auger stem is added onto the driver stem.



Pipe Jar Devices.

By referring to the cut you will note that the pulling plug through which the driver stem works screws into the coupling. Plugs which screw on the outside of pipe are also made, but the coupling plug is more convenient and is better constructed.

The knocking head on the stem is usually screwed on with straight threads and the stem beaded over below it.

In operating a device, the tension on the drill rope should be so adjusted that the jarring head hits the bottom of the pulling plug just as, or a little before, the crank passes lower center. This will result in a strong upward blow.

To increase the force of the blow, the spudder should be run on the back stroke and the engine speeded up so as to give the tools a quick, lively motion. A little experimenting will soon show you the proper tension to carry, also the proper speed to run.

During driving operations the pulling plug should be tightened up from time to time for should it be allowed to become loose the threads may be stripped.

Under certain conditions, mainly when the pipe is being pulled through beds of sand or gravel, better results can be obtained by allowing the driver to strike on both the up and down strokes. The writer is unable to give an exact reason for this but it seems as though the down blow tends to loosen the pipe so that the up blow has a chance to be effective. The advantage of a down blow has long been recognized by drillers, it often being used in connection with a pry-pole.

When thus used a strain is taken on the pipe with the pole and the pipe struck by bolting the drive clamps onto the stem and then driving down.

The writer has used this method on several occasions when no other appliances were at hand and has found it very satisfactory for short strings of drive pipe.

As stated under "Pulling with Pry-Pole," the pry pole is often used in connection with the pipe-jar device. When thus used, a strain is taken on the pipe with the pole and then the pipe driven upward with the driver. The pry-pole is quite an advantage where a long or heavy line of pipe is being driven up as the pole will tend to carry the weight of the pipe, thus allowing all of the force of the blow to be used in loosening and moving the pipe.

Besides using the pry-pole with the driving device, the ring and wedge puller is also used. As a rule the ring and wedge is used only on the most stubborn jobs, as the pry pole can be handled much quicker and with much less labor.

As stated on page 45, it is sometimes necessary to pull the drive pipe 3 to 4 feet when dynamiting boulders, and inasmuch as pipe jar devices are most generally used for this purpose, the following instructions regarding the handling of the battery wires in connection with these appliances are given.

Owing to the fact that it is necessary to screw a plug into the end of the pipe, also owing to the fact that the driver stem has a play of from 2½ to 3 feet in the upper end of the pipe, it is impossible to allow the battery wires to come out the top and thus provision must be made for taking care of them in a different manner.

There are two ways of doing this. One is to screw a short piece of drive pipe about 4 feet long, into the end of the pipe to be pulled and then screw the pulling plug into the coupling on the upper end of the short piece. At the bottom of the short pipe and about 6 inches from the end, a hole ¾ to 1 inch in diameter should be drilled.

In handling the wires, pass them through the hole before the short piece of pipe is screwed on and then shove enough of the wire down into the hole so that there will be ample slack to prevent the wires from being broken when the pipe is screwed on. After the pipe has been set up, take up the slack in the wire.

You are now ready to screw the pulling plug into the coupling and begin operations.

As the pipe is driven up a careful feel of the wires can be maintained so that you will be able to determine whether or not the dynamite is staying in place.

The other method of taking care of the wires is to use a four-foot piece of pipe on top of the drive pipe and allow the wires to hang from a stick placed in the coupling connecting the four-foot piece to the drive pipe. The stick should be of hard wood about 1½ inches wide and 5/16 inches thick and should be of such length that it fits snug in the coupling.

In placing the stick, it should be shoved down into the coupling until it rests on top of the pipe. Now fasten the wires securely to the stick, first allowing 10 or 12 feet of slack in the wires below the stick. Next screw in the short length of pipe and you are ready for adjusting the pipe puller and going ahead with the work.

The stick method of fastening the wires has the advantage that it is not necessary to drill a hole into the pipe, but it has the disadvantage that it is impossible to keep a feel on the wires.

## Re-Casing a Hole.

In water well work the re-casing of a hole is generally for the purpose of shutting off a caving formation or else for shutting off a stream of undesirable water. There are also cases where a hole is re-cased in order to prevent the water of the well from draining off through porous or creviced ground, also for preventing the water from coming in contact with formations such as coal, gypsum, sulphurous shales, alkali rock, etc., which will give to the water undesirable qualities.

While the re-casing of a hole is theoretically a very simple matter, involving as it does only the screwing together of joints of pipe and the lowering of them into the hole, still the practical operation requires the exercise of good judgment and a close attention to details, if accidents are to be avoided. On short holes the necessity for exercising extreme care is not so great, but where a long line of casing is being handled the weight is often enormous and thus the least slip or mis-movement may result in dropping the casing and plugging the hole.

To handle a re-casing job in a satisfactory manner the driller should be provided with the proper tools and should also arrange the drilling rig for the work at hand.

The arranging of the rig depends upon the amount of casing to be set. If the weight is not great, it may be possible to lower the full string direct with the drilling cable. If, however, the weight will be considerable, it is not safe to adopt this method.

The amount of casing that can be handled direct with the drilling line depends upon the size of the machine being used. As a rule it is safe to figure that an amount of casing equal to two times the weight of string of tools can be lowered direct with the drilling cable without the use of blocks. Thus if the machine you are using can handle a string of drilling tools weighing 1,000 pounds, it is safe to figure that a string of pipe weighing 2,000 pounds can be lowered by the cable. Taking 4 inch pipe as a basis of measurement, this rig would then be able to lower about 200 feet of pipe, as the table on page 34 shows that 4 inch pipe weighs approximately 10.72 pounds per foot.

It is best, when using the cable direct, or even when using blocks, to have only one or two wraps of the rope on the drum as the hoisting power will be much greater than if the drum is full. For re-casing work some drillers remove the regular drill cable and then use a short piece of cable which they have especially for this purpose. When quite a bit of shallow re-casing work has to be done from time to time this is a pretty good plan as the rope can be cut to such length that just the proper amount can be left on the drum. Also the rope can have a hook spliced onto the lower end, thus making it possible to easily hook into the elevators, casing swivel, or whatever is used for handling the pipe.

If you are going to use your regular drilling cable the tools should be unscrewed from the rope socket and laid to one side. In order to handle the work rapidly and to do away with the necessity of using a chain, a pin hook as shown on page 120 should be screwed into the box of rope socket. If a pin hook is not available the regular drive clamps as shown on page 27 can be fastened to the square of rope socket and then a chain passed over the clamps and around the socket and fastened thereto. If you are using elevators, or a casing swivel, the chain can be hooked through these before being fastened to the socket.

The chain will prove very satisfastory for short lines of pipe but it should never be used where a considerable weight has to be set as it never gives warning when about to break and besides, it may become kinked and let the pipe drop an inch or two, this slight drop giving enough momentum to the pipe to part the line.

A short drop is something which must never occur when any considerable amount of pipe is being lowered as even a drop of an inch or two places an enormous strain on the whole hoisting system. One of the most frequent causes of these drops is the slipping of rope on the drum, this being caused by a strand of the rope rolling off of the next higher strand. This can be avoided by seeing that the rope winds on the spool evenly. Another cause is the pipe "hanging up" on a "bump" in the hole. It sometimes happens that a "bump" will hold the pipe just enough to allow the rope to slack and then when the full weight rests upon the obstruction, the pipe is forced on past and drops the full length of the slack which has been let out. To avoid this danger the pipe should be lowered slowly, and carefully watched, and at the first sign that it is not moving down, the brake should be set, or if the line has slacked off a slight amount, the hoist should be thrown in gear and the slack taken up. Next let off sufficient slack to allow just a small amount of the weight of the pipe to rest upon the obstruction and then by placing the chain tongs on the pipe, twist it slightly to the right. If this does not bring results, allow just a trifle more weight to rest on the obstruction and twist again. If you are still unable to move on down then the pipe should be removed from the hole so that a reaming tool can be run, and the bump or crook cleaned off.

It may appear to some that the removing of the full line of casing is too troublesome a proposition and they will thus try to force the casing on down. While it may be possible in a few cases to force the pipe past obstacles, without going to the trouble of reaming, still it is a dangerous procedure as sooner or later, if the practice is kept up, the casing will be dropped and the amount of time lost in cleaning one hole will be much greater than the time saved on several jobs where the pipe has been hoisted.

Not only is it dangerous to attempt to force casing into a hole, but it is also unwise for other reasons as it may involve serious trouble if an attempt is ever made to remove the casing. It is much better to make everything right as you go along even if it does seem to take a little extra time.

Other conditions which will cause trouble in re-casing, are crooked holes and flat holes. When these conditions exist it is necessary to run the reamer and put things in shape.

A hole which drifts a slight amount will, as a rule, not be troublesome to handle as the casing will adapt itself to the slight variation. However, when the turns or bends are of such sharpness that the casing "hangs up," it is dangerous to attempt to force matters as the threads are liable to be sprung in the coupling and thus the string of casing may be pulled apart.

When preparing to set a considerable amount of casing, shear poles should be placed out in front of the derrick and blocks and fall lines should be arranged as explained on page 167. When blocks are used, it will be necessary to remove the drill cable from the drum and thread up the blocks with a wire cable as a wire line will prove more satisfactory than any other style of rope.

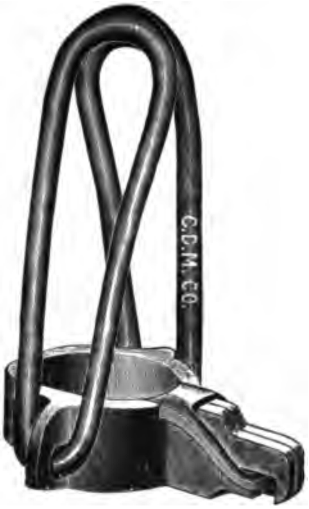
If an extremely heavy load will have to be carried it will be well to block up under the axle which supports the derrick end of machine so as to take the heavy strain from off the wheels.

The tools usually used in re-casing, outside of the drilling rig, shear poles, pulley blocks, etc., are elevators, casing swivels, pipe clamps, chain tongs and casing pole and rope. There are also a few other special tools and appliances which are used and which will be described as we go along.

The first thing to do in starting a re-casing job, after the surface equipment has been arranged, is to lay out the casing so that it will come to hand conveniently. In the majority of cases this can be best done by piling up the casing out in front of the hole and in line with the machine. The ends of the casing with couplings on them should be pointed towards the hole and should not be over 8 or 10 feet from it. Before starting the actual work of re-casing, all of the couplings should be carefully examined to see that none of the threads are in bad shape, as the work, once started, should not be held up on account of troubles which are easily preventable by a little foresight. It is to be supposed that the threads on the pipe are protected with safe ends and thus do not need attention.

The first joint of casing to go into the hole should have a coupling screwed onto the lower, as well as the upper end, the bottom coupling serving to protect the pipe and prevent crimping.

Before lowering the first joint into the hole, the pipe clamp shown on page 42 should be placed over the hole and spread apart a sufficient distance to allow the pipe to pass. After the first joint has been lowered until the bottom of coupling comes within an inch or two of the top of clamps, the clamps should be tightened up until the pipe is firmly held. In order to prevent twisting of the clamps, two heavy ground timbers should be placed close to the hole, one on either side, and leveled up so that when the clamps are drawn up, the pipe will hang plumb.



Casing Elevator.

The tool to use in handling the pipe may be either a casing swivel as shown on page 138 or a pair of elevators as shown in accompanying cut. The casing swivel will prove satisfactory for light jobs but on heavy work the elevators are to recommended, as they are not only safer but with them casing can be more readily handled. Elevators should be used in sets of two as one pair should be left on the pipe to hold it until the next joint is connected up. When elevators are used, it is not necessary to tighten up the pipe clamps each time a joint is lowered as the base of elevators is sufficiently broad to straddle the blocks.

Elevators are made in several different styles, the pair shown in cut being known as Fair's Patent, this being one of the best types on the market. Elevators can also be obtained made of either malleable iron or wrought iron. For light work, some drillers prefer the malleable iron elevators owing to their lower cost, but on heavy work nothing but the wrought iron ones should be used.

In connecting up casing each joint should be set up full length of the threads or otherwise the string of casing may part should it be necessary to take a heavy pull upon it. If the threads are heavily oiled, it will make the setting up of the joints much easier. A mixture of vaseline and graphite as described on page 217 is good dope to use.

When a long line of casing has to be lowered the weight can be greatly decreased by partially filling the hole with water and then screwing a casing disc into the coupling on the lower end of casing. A casing disc is made of cast iron and is threaded so as to make a water tight fit when screwed up. After the casing has been set, the disc can be removed by lowering the drilling tools and striking the disc a blow or two.

If the casing is used for the purpose of holding out a heavy pressure of water, the bottom of the hole for a distance of 6 or 7 feet should be filled with drill cuttings which will settle around the outside of casing thus making a tight connection.

Some drillers when setting casing to hold out a heavy water pressure, wrap the bottom of the first joint with several wraps of dry rope, which when it comes in contact with the water in the bottom part of hole will swell up and assist in making a tight joint. If rope is used it should be thoroughly dried out and should be small enough to allow the casing to be inserted without binding.

Should it happen that casing is set in rock so much cracked or creviced as to allow the water to drain down along the casing and enter through the openings in the rock, it may be possible to seal the rock by dumping stiff clay in the hole and puddling it by using the drilling tools. The puddling will force the clay into all the seams and if the water pressure is not heavy the clay filling may prove sufficient to hold the water in check until the desired lower stream is struck. If the lower stream rises as high, or nearly as high, as the upper stream, it will balance the pressure and prevent further trouble. If, however, a heavy pressure of water is to be cased off, the writer would not recommend the clay method. for even should you succeed in holding out the water temporarily, the clay filling is liable lo break down even long after the well is finished and the repairing under such conditions will be an expensive undertaking.

The best plan to adopt under such conditions is to pull the casing and drill the hole down below the shattered portion of the rock and then set the casing again.

## Pulling Casing.

As a rule, casing can be pulled with pulley blocks and shear poles as rigged up and described on pages 167 and 168, also as explained under "Re-casing a Hole." It is, however, sometimes necessary to use the ring and wedge device for starting the casing as the sediment may have settled so firmly around the outside as to hold it. The use of the pipe driver as described on page 169 may also be of assistance.

After the casing has been loosened the surface equipment should be arranged the same as recommended for "Re-casing a Hole," that is, the ground timbers should be placed on either side of the hole and the clamps placed on top so as to straddle the casing.

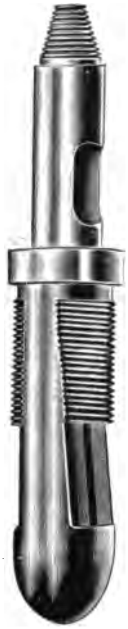
In handling the elevators, the casing is hoisted until the coupling on top of the second joint shows up, then the pair of elevators which are not in use are fastened around the casting just below the coupling. The hoisting line is now slacked off and the weight of the full string of tools allowed to rest on this pair of elevators. The first joint of casing is now unscrewed and removed, and the same performance gone through with for each joint.

When unscrewing a joint be sure to see that the upper joint of pipe is unscrewing from the coupling and not the coupling unscrewing from the second joint, for should the coupling unscrew from the lower joint, the whole string of casing will be dropped.

In fishing for casing which has been dropped in the hole or which has been left in the hole due to the casing pulling apart, the tool most generally used is a casing spear. Two types of spears are made—Bulldog spears and Trip spears. The accompanying cut shows construction of Bulldog spear.

The Bulldog spear gets its name from the fact that when it once takes hold it cannot be made to let loose. The Trip spear on the other hand, is so constructed that by shoving it on down to the bottom of the hole, the slips are pushed up along the tool and held from taking hold by being caught by a trip or trigger.

Casing spears are made with regular drilling tool joints so as to be used on a set of jars with a stem above, and are also made so that they can be used on a string of casing or pipe. If there is only a joint or two of casing to be recovered, the spear can very safely be used on a string of tools, but if there is quite a bit of lost casing in the hole, the pipe will work better and will be safer.



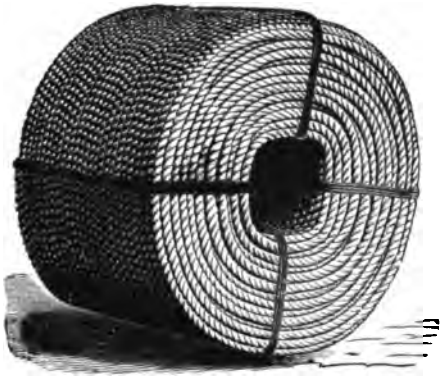
**Bulldog Casing Spear.**

At times it will be found that the full string of casing cannot be pulled all together and under such circumstances a casing cutter is lowered into the hole and an amount of casing such as can be handled, cut loose. This is repeated until all the casing is recovered.

Sometimes casing is held very firmly in the hole by a large amount of sediment on the outside. Under such circumstances long slots are cut in the lower joint, these slots allowing the sediment to work itself into the inside of the casing, thus making it possible to get it started. The tool used for this purpose is called a casing splitter and is usually used below a set of long stroke jars with a heavy stem above.

# PART V.

## Drilling Ropes and Cables.



Soft Laid Rope as coiled for shipment.

Hawser Laid Cable as coiled for shipment.

All ropes are made of fibres taken from certain plants or trees. As there are many different kinds of fibres suitable for rope making, we thus have a variety of different classes of ropes. The most commonly used ropes are made of either jute, sisal hemp, coir, flax, cotton, hemp or Manila hemp.

Owing to the fact that Manila hemp can be obtained in long fibres of great strength and owing to the fact that water does not damage the fibres, manila hemp makes an ideal substance for drilling cables.

In the beginning of the drilling business rope made from sisal hemp was extensively employed, and while the sisal fibres are of great strength, yet they will not stand rough usage like manila and besides the sisal will rot in the presence of water.

While ropes are made in several different "lays" or "twists" the only lays in which the drill man is interested are the "soft lay" and "hard or hawser lay."

Soft laid rope is usually composed of three plys, each ply being composed of several strands which in turn are made up of the fibres. The three main plys in this style of rope are always twisted to the left.

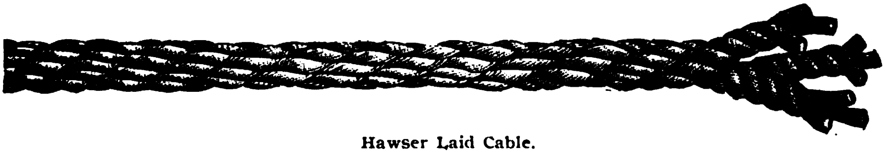
Hard or hawser laid rope is composed of three main plys, each ply being composed of three other plys. This style of rope is in fact simply three soft laid ropes twisted together. Inasmuch as the plys of the soft laid rope are twisted to the left, the hawser laid rope is formed by twisting the three soft laid ropes to the right. As the main plys of hawser laid rope are twisted to the right, and as the plys of soft laid rope are twisted to the left it is impossible to splice a soft laid into a hawser laid rope.

For hollow rod drilling, inasmuch as the rope is not required to go into the hole, and as rod drilling requires a rope of as great flexibility as possible, the soft laid rope is to be recommended. The soft rope is also to be preferred on account of the fact that it can be spliced much more easily than the hard rope, and thus is much more convenient for splicing in the swivel hook.

Soft Laid Rope.

For cable drilling nothing but the hawser laid rope should be used. The reasons for this are as follows: hawser laid rope does not untwist as easily as the soft rope and thus the rope remains much stronger. Being twisted together firmly the rope is much harder than the soft laid rope, and thus is not so easily frayed by coming in contact with sides of drill hole.

Another advantage possessed by having the rope solidly twisted is, that as the soft laid ropes comprising the cable cannot untwist, it prevents the cuttings from coming in direct contact with the individual fibres of the rope. As it often happens that the drilling is done through many feet of water, and as this water is full of sharp cuttings, it is necessary to use a rope so constructed as to prevent this grit from entering between the fibres, as the presence of any abrasive substance in direct contact with the fibres will soon result in parted strands.



Hawser Laid Cable.

Hawser laid Manila cable for drilling purposes is, broadly speaking, furnished in two grades; one the regular grade of commerce, and the other a special grade known as Manila cable, bolted stock.

The ordinary cable is composed of fibres of varying lengths, and the number of strands in a ply range from 16 to 18.

In hawser laid, bolted stock rope, the fibres are selected, being the longest and most perfect obtainable. As all the fibres are long, the strands composing the plys can be made smaller and more numerous, thus making it possible to twist the rope closer. Where an ordinary hawser laid rope contains 16 to 18 strands to the ply, a hawser laid rope of bolted stock will contain from 26 to 28 strands to the ply.

In drilling, inasmuch as the tools are alternately lifted and dropped, the strain comes on the rope intermittently, and thus the rope is successively stretched and allowed to contract. It is this alternate stretching and contracting which causes the greatest wear, as the plies of the rope, rubbing against each other, at the center of the rope, soon fray the fibres. Many remedies have been tried in an attempt to prevent this internal friction, but as yet nothing has been found which will wholly eliminate the trouble. Some rope makers have tried using a soft hemp centre heavily lubricated, but this has proven unsatisfactory. Nearly all rope makers now lubricate the various plies, composing their ropes, and this is of some benefit, but as the oil or lubricant is soon worked out, the effect does not last long.

A drilling cable used in a moist climate will last much longer than one used in a dry, hot climate. The reason for this is that the heat drives the oil and moisture out of the cable and leaves the fibres dry and brittle. If a cable is not to be used for some time it should be taken off the machine and placed either in a cellar or some place where the air is cool and moist. Should the cable be put in the cellar it should be placed on planks so arranged that it will be lifted 5 or 6 inches off the ground.

Besides the internal friction referred to above, the rope is also subjected to a friction against the sides of the hole, which frays the fibres of the strands on outside of rope.

If the hole is kept straight and if the rope is kept at proper tension, this external friction is not great, but if the hole is crooked or if the rope is run too slack, the wear becomes excessive. Another cause of undue wear is the presence of rough places in the drive pipe or casing through which the drilling is being done. These rough places are sometimes due to blisters in the iron, but more usually if there is a roughness in the pipe it will be at the ends where the cutting of the pipe has turned the edges inward.

On small drilling rigs where the holes do not exceed 300 feet in depth and the drilling is done altogether with the spudder, it is a good plan to run a cable until it shows quite a bit of wear and then reverse the cable by putting the end which was in the socket, on the drum. This will even up the wear on rope and will make it last longer.

In buying drilling cable, you should, if possible, buy it of some reputable drilling machine manufacturer, as the manufacturers are in a position to know what companies make the good rope and besides they are always anxious to furnish their customers with the best.

There are two rope companies in the United States at the present time whose drilling cables are of the very best, but unless the driller buys his rope from the drill manufacturers or some very large jobbing house, he will never get any of these cables, owing to the fact that these two concerns will supply cable only on long time contracts calling for large amounts. Another reason why these cables are hard to procure is because cables made by these two concerns sell for from ½ to 1 cent per pound more than other makes of cables and thus most retailers are averse to handling it owing to the fact that their profits are not as great as on the cheaper brands.

We do not mean by what we have just said to cast any reflection on the retailers, as in 99 cases out of 100 the retailer is not well enough posted on drilling cables to know that by paying ½ to 1 cent more per pound he can obtain a far better cable, and as the drill man usually insists on as low a price as possible, it is natural to expect that the retailer will buy where he can buy cheapest.

In this connection we desire to add a bit of advice, and that is, insist on good cable and be willing to pay a good fair price for same. A good drilling cable at 15 cents per pound is much cheaper in the long run than a poor cable at 12 cents per pound.

In buying cable you will note that it is sold by weight. The following table gives the approximate weight, circumference and breaking strain in pounds, of the most commonly used sizes.

| Diameter Inches | Circumference in Inches | Weight per 100 ft. | Breaking Strain in pounds |
|---|---|---|---|
| 1 | 3 | 38 | 8,500 |
| 1¼ | 3¾ | 60 | 10,600 |
| 1⅜ | 4¼ | 70 | 13,500 |
| 1½ | 4½ | 82 | 16,400 |
| 1⅝ | 5 | 104 | 18,750 |
| 1¾ | 5½ | 125 | 22,700 |
| 1⅞ | 5¾ | 138 | 27,000 |
| 2 | 6 | 147 | 29,000 |
| 2⅛ | 6⅛ | 162 | 32,000 |

To obtain the working strain of a hawser laid rope of given size, divide the breaking strain by 3.5.

The size of cable to be used is determined by the weight of tools and the depth of hole to be drilled.

Under "Rock Drilling," it was repeatedly stated that it is necessary to drill on the "spring of the cable," if the best speed is to be made, and in order to get this "spring" it is necessary to use a cable of certain size for tools of a certain weight. Thus, if tools weighing but 500 pounds are hung on the end of a cable 2 inches in diameter, the blow delivered will be "dead" as the tools are not heavy enough to stretch the rope. On the other hand, if tools of great weight are hung on a small rope, the rope soon has all the life pulled out of it, and not only does it lose its "spring", but it is soon stretched beyond its limit, and thus a fishing job results.

The table below gives an approximate idea of the sizes of hawser laid cable usually furnished with different sizes of tools.

As the size of drilling tools is figured from the stem, this is the only part of tool equipment listed.

You will note that the table also contains a column covering the depth of hole usually figured on being drilled when tools of a certain weight and rope of a certain size are used. This column is, of course, not set down as an arbitrary standard, but simply as an approximate guide in order to get some sort of a comparison between the size of rope, size of tool equipment and depth of hole.

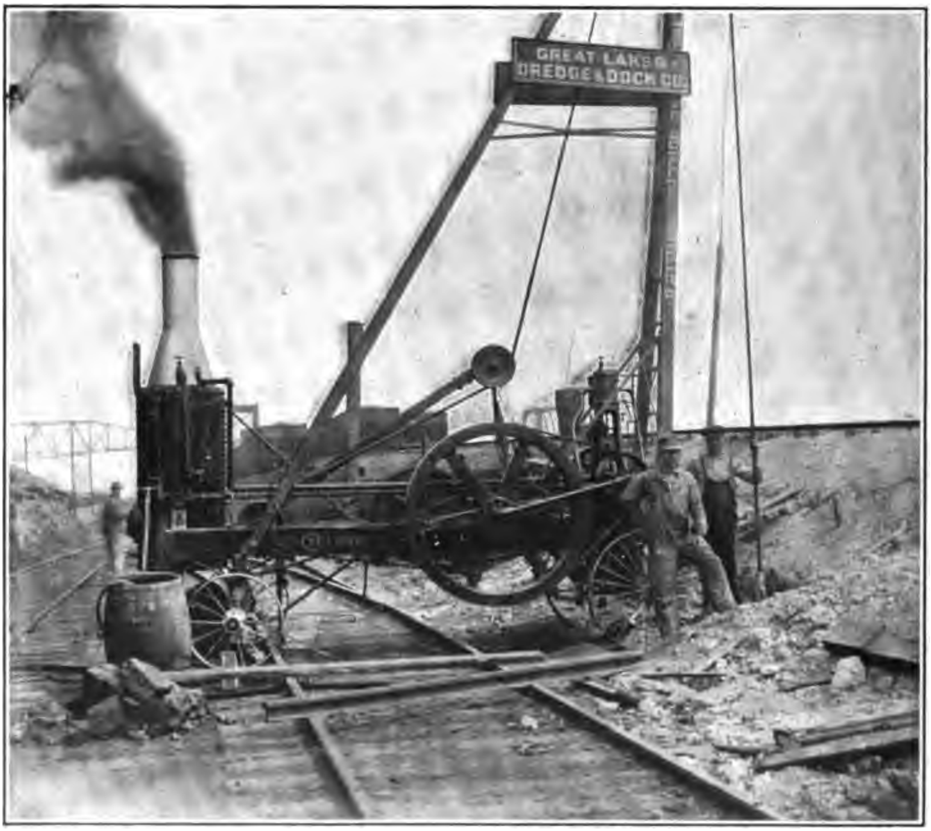
It is readily apparent that under certain conditions, the tool equipment will also depend upon the size as well as depth of hole and thus under special cases, when large holes are to be drilled in rock, even though the holes are not of considerable depth, it would probably pay to use a very heavy string of tools. However, the list as given will be found to cover pretty closely the requirements of ordinary well drilling.

| Size of Stem | Diameter of Rope | Depth of Hole to be used in |
|---|---|---|
| 3 in. x 12 ft. | 1⅜ in. | 150 ft. |
| 3½ " x 12 " | 1½ " | 250 " |
| 3¾ " x 12 " | 1½ " | 300 " |
| 3¾ " x 13 " | 1⅝ " | 350 " |
| 4 " x 13 " | 1⅝ " | 350 " |
| 4 " x 14 " | 1⅝ " | 400 " |
| 4 " x 16 " | 1¾ " | 500 " |
| 4 " x 18 " | 1¾ " | 700 " |
| 4 " x 20 " | 1¾ " | 900 " |
| 4 " x 24 " | 1⅞ " | 1200 " |
| 4¼ " x 26 " | 1⅞ " | 1600 " |
| 4¼ " x 32 " | 2 " | 2000 " |

A close watch should be kept upon the cable at all times, to see that no strands are parted. Each time the cable is pulled out of the hole, the driller should scan every inch, as it passes before his eyes, and if any strands have parted so that the ends project, the rope should be carefully examined at that point.

Probably the most particular point to watch is just above the rope socket. At this point, the tremor, which vibrates through the rope at each stroke, is suddenly arrested and the tendency is to shear the rope right at top of socket. While of course this shearing tendency is not great for any one blow, yet the repeated attacks on the cable at this one point, finally result in making the fibres so brittle that they easily part. On shallow wells this vibration is not so troublesome, but on deep work the socket must be reset quite often. In resetting socket, the rope should be cut off for a distance of from 10 to 25 feet, depending upon condition of same.

After a cable has been completely worn out, it can be sold to junk dealers, and should bring from 1 1-2 to 3 cents per pound.

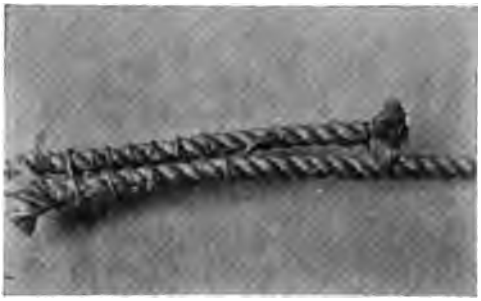


No. 4 Cable Drill, drilling holes along lake front for placing of anchor bolts.

# Knots and Splices.

## Manila Rope.

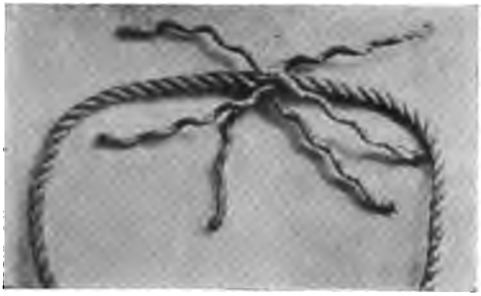
Watch the foreman of a rigger gang as they are hoisting a heavy girder or beam into place and you will notice how carefully he watches all the knots and hitches that are made to secure the hoisting rope to the timber.



One way to join two ropes.

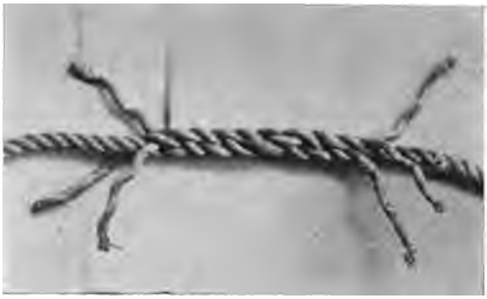
You will hear such phrases as "put on a timber hitch," "throw in a half hitch," "hang up a cat's paw," and to one unfamiliar with these hitches they seem very difficult to make. To those familiar with rope they are but the work of an instant. Anyone can tie a knot, but to tie a knot that will not jam, and can be easily and quickly untied is the secret of all knot tying. A great amount of rope and cordage is destroyed by not being properly tied. It has been told of a robber that he tied his horse so tightly he was unable to untie him quickly and he therefore had to cut the rope, the part left tied to the post furnishing evidence which secured his conviction.

In joining two ropes together it is necessary to have the rope as strong at the splice as at any other part. If it is used for hoisting it should be of no larger diameter than the original size of the rope.



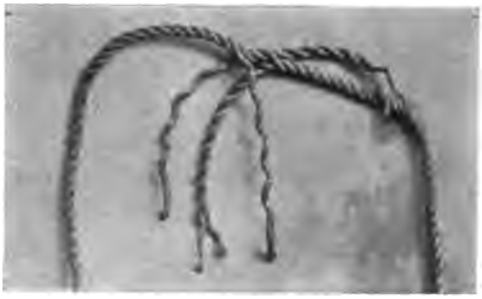
Simply unwind the ends and lay them together.

Splices can be made very quickly and where a strong, quick splice is desired it can be done by unwinding the ends of the rope and by simply braiding the ends together you have a simple and very strong splice, but it is thicker than the original diameter of the rope.



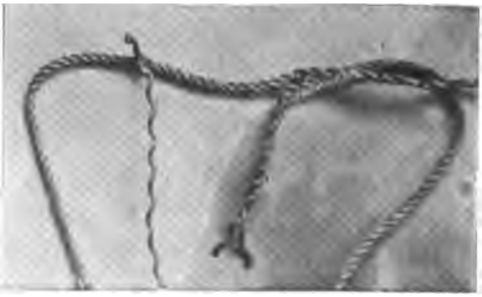
And you have a very simple strong splice.

A very strong and serviceable splice can be made by unwinding one strand for several feet and laying the rope together winding one strand into the rope as the other is unwound.

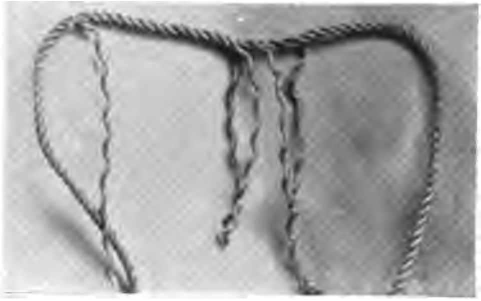


Rope laid together ready to weave into the strands.

After it is in place unwind the two remaining strands following the one which is wound in the opposite direction from the one first laid in.

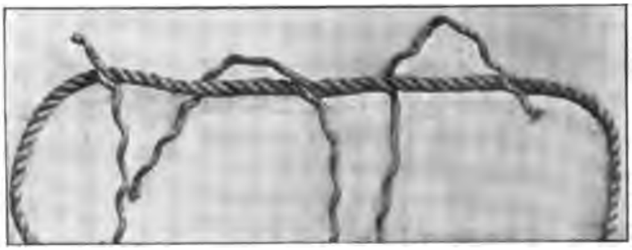


One strand wound into place.

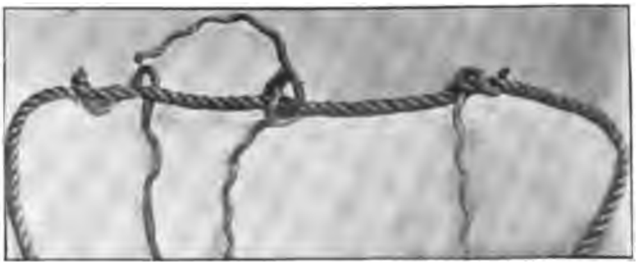


Unwind strand to the right and follow with another strand.

Thus you have two strands laid in opposite directions and ready to tuck. This can be done by crossing one end over the other and tucking the end under the strand or by drawing the ends in a knot and tucking them under the strands as before, thus we have a very strong splice, and if the ends are properly tucked in it will be no larger than the original diameter of the rope, and can be used over pulleys or where it is necessary that the splice be no larger than the original diameter of the rope.



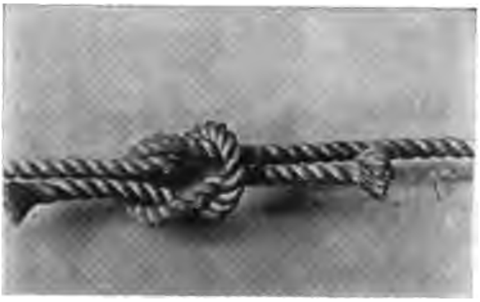
Strands laid in ready to fasten.



There are two ways of fastening the ends.

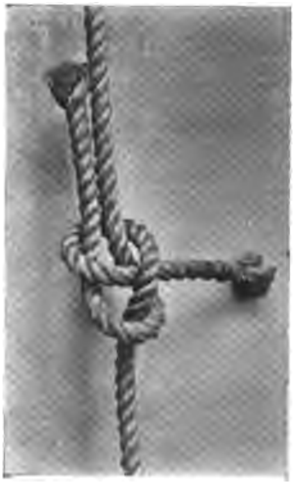
Both Ends spliced together.

Two ropes can be joined by a square or reef knot. It will hold tight and not jam unless with a small size rope.

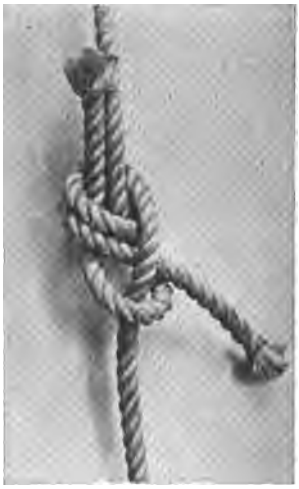


Square or reef knot, commonly used to join two ropes together.

Another safe way to join two ropes is a plain bend or a double bend, this knot can be untied very easily and is stronger than any part of the rope.



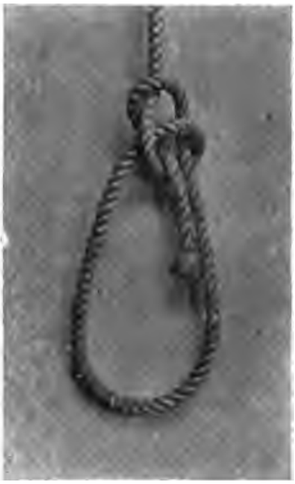
Plain Bend.



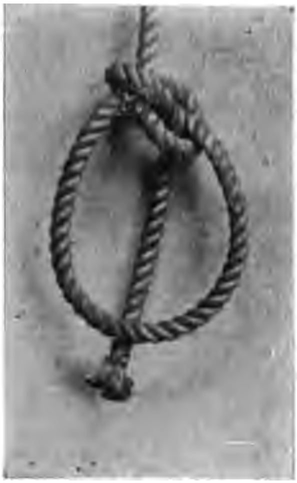
Double Bend.

A Bowline is very useful where it is desirable to have a loop that will not slip at the end of the rope.

Another form of Bowline which is sometimes used, is made by taking the end of the rope through the opposite way.



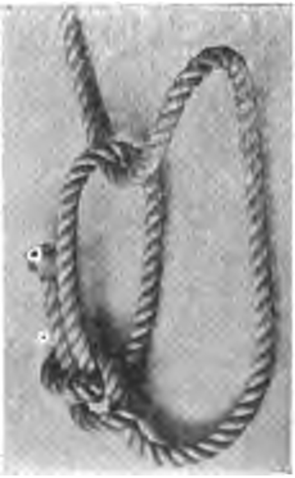
Bowline.



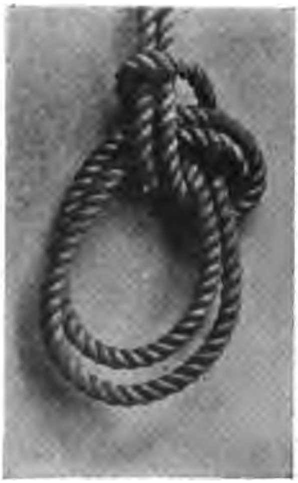
Bowline.

The only safe slip knot is the Running Bowline which will tighten and not bind the rope.

A very safe knot is the Bowline in the Bight. It is a double bowline and makes a very strong hitch in the middle of a rope.

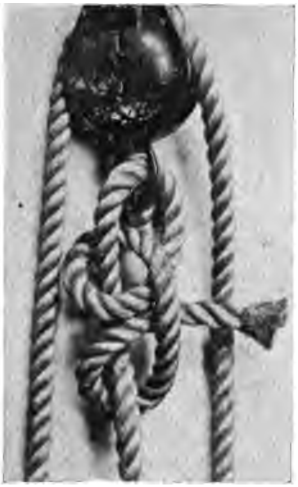


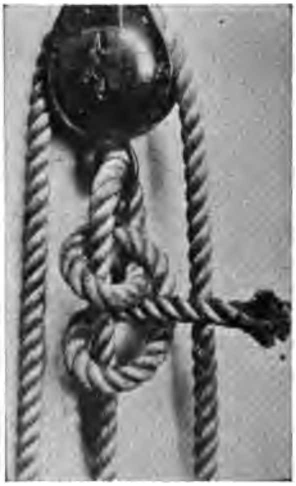
Running Bowline.



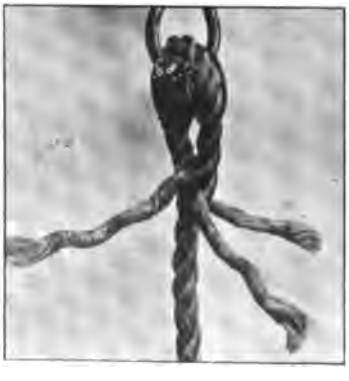
Bowline in the Bight.

A very good way to fasten a rope to a becket in a pulley or around a beam is two hitches which can be strengthened by taking a round turn also. There is a difference of opinion in regard to tying these hitches but either of them is very strong.

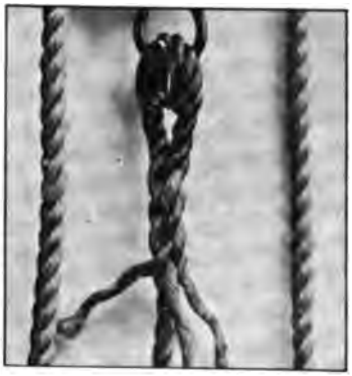

Two Hitches.


Two Hitches.

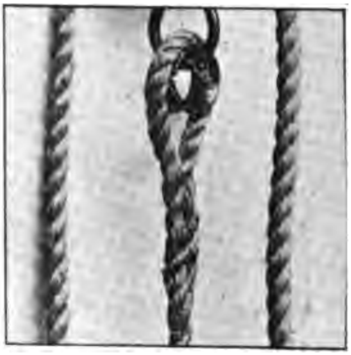
A very good way to fasten a rope to a becket or hook, or where it is not necessary to remove it, is a half splice, which makes a very neat and strong way to securely fasten the rope. By unwinding the rope for several turns and starting two strands through, bringing them out between different strands on the opposite side you have the splice started, which is very easy to complete, and by trimming the ends they can be tucked under the the strands, making it tapered to the end.


To start a Half Splice.

There are a great many hitches that are useful and very effective when used for the purposes for which they are made.

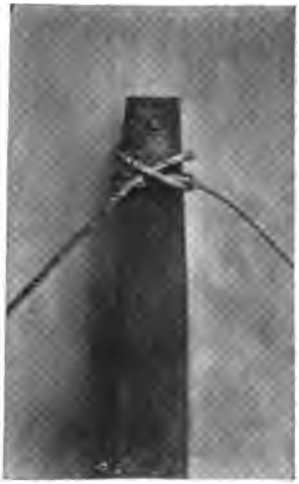


Half Splice properly started.

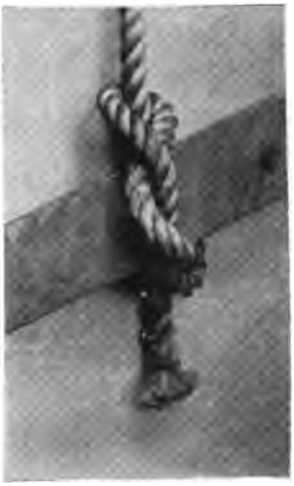


Half Splice, a very good way to fasten a rope to a becket or timber.

A clove hitch will be found very serviceable for holding the top of a post or beam in a perpendicular position. It will bear the strain on either side of the knot without slipping, thus a long rope can be used for two guy lines.



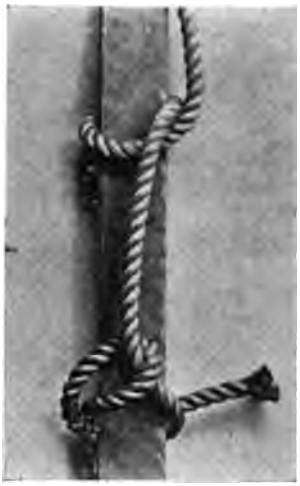
Clove Hitch.



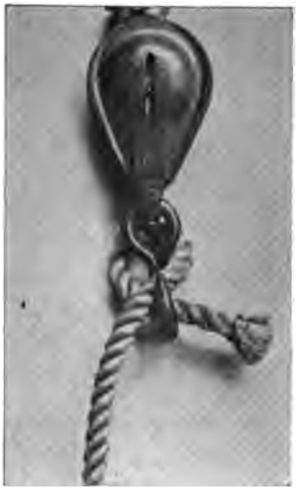
Timber Hitch.

A very effective hitch for hoisting and lowering timber in a mine is the timber hitch. This is ridiculously simple, yet very effective, and when used in connection with a half hitch can be used to keep a piece of pipe or timber in a perpendicular position.

A Backwall hitch is made by a twist of rope which secures one object to another and can be also safely made with a chain.

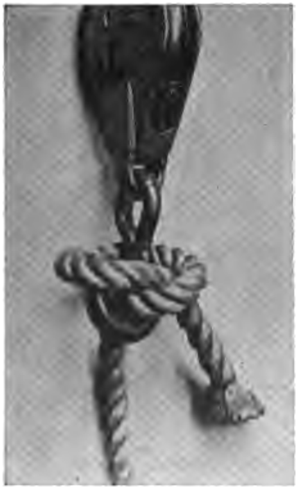


Timber Hitch combined with Half Hitch.

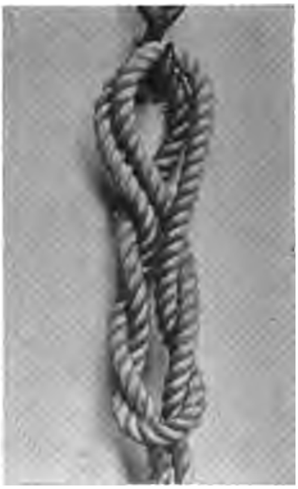


Backwall Hitch.

Another effective hitch can be made which is more complex but is useful for a hook that is strained or much rounded.



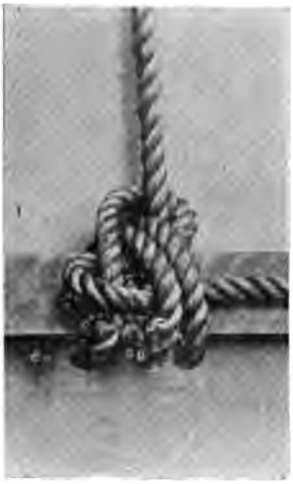
This knot is not properly made. Note the rope on the right side of hook.



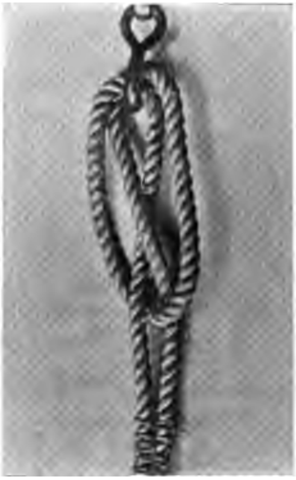
Cat's Paw.

A Cat's Paw is famous for its enormous strength. It is simply an endless loop and is stronger than any other part of the rope.

Another strong timber hitch which is very serviceable, but is rarely used, is the Hilliard Bend. This knot will not slip under the most severe strain, making it reliable at all times.

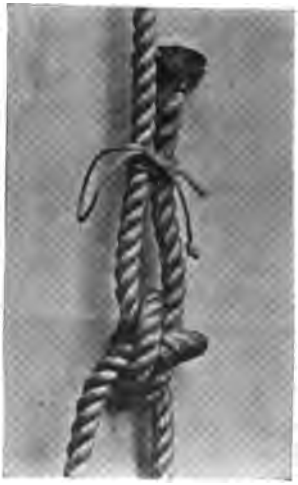


Hilliard Bend.

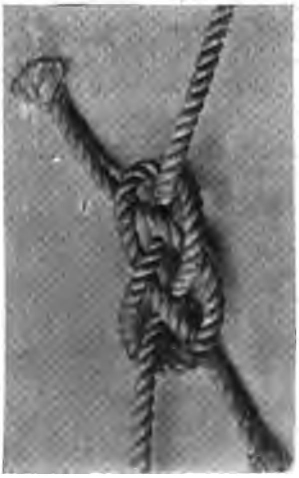


Clove Hitch for sand pump or bailer.

A very good way to fasten the end of a wire or Manila rope to a hook or at the top of a bailer is to make a Clove Hitch and tie the loose end to the line. This can also be made stronger and more effective by putting in a half splice. It will wear a long time and will not draw tight.



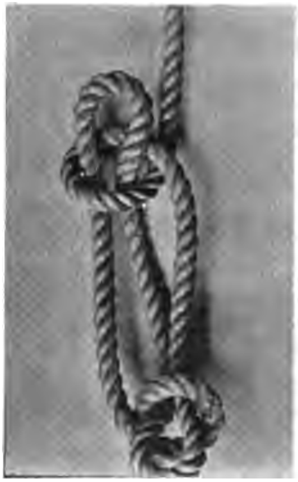
Rolling Hitch.



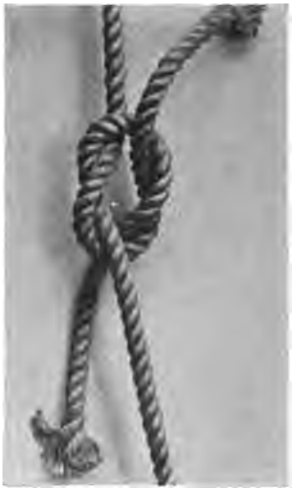
Garrick Bend,

A Rolling Hitch is very useful to fasten one rope to another where it is necessary to strengthen it.

A knot that is useful in tying two large ropes together is what is commonly called a Garrick Bend. It is rather hard to tie, but strong, especially for hawser laid rope.



Sheep Shank.



Granny.

When a rope is too long it can be shortened very nicely by putting a Sheep Shank in the rope. This makes a very good way to shorten it.

The knot that is easy to tie and liable to slip, also hard to untie, is the Granny. This knot is tied by people of all ages, has caused no end of profanity in trying to untie it, but still is universally used. It comes as natural to tie this knot as does sin, and to untie it—well, cut the rope, that is the best way out of it.

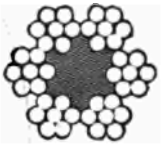
Knot making is a very useful hobby and a liberal education in this line comes in handy. Everyone should learn to tie at least the simple knots so they may be easily untied.

# Wire Rope.

There are a number of different types and kinds of wire rope made up to meet different requirements and uses. There are about five standard constructions, not including guy lines, that are in every day use. There are many more especially constructed ropes for various uses.

The standard sizes are principally all made up of six strands ranging from 7 to 37 wires to the strand. The strands are all wound on a hemp center.

Two types are used in connection with drill work, one for sand lines and the other for drilling cable.



**Sand Lines** are made of *crucible cast steel*, composed of 6 strands, 7 wires to the strand, with a hemp center. These are used in sizes ranging from 9/32 to 3/8 on portable drills; larger sizes are sometimes used on standard rig outfits.

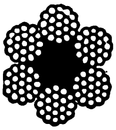
9/32 in. is suitable for handling bailers 3½ in. x 12 ft. or smaller. The approximate breaking strain is 2.8 tons, allowable working strain ½ ton.

5/16 in. sand lines are suitable for bailers 3½ or 4 in. x 18 to 20 ft. long; breaking strain 3.4 tons, allowable working strain ¾ ton.

3/8 in. will handle any size bailer that can be handled on a large portable drill. The breaking strain is 4.8 tons, allowable working strain 1 ton.

The average weight per foot covering these sizes is 0.12½, 0.15, 0.22 respectively.

**Steel Drilling Cables** are made from *plough steel*, 6 strands and 19 wires to the strand, with hemp center and left lay.



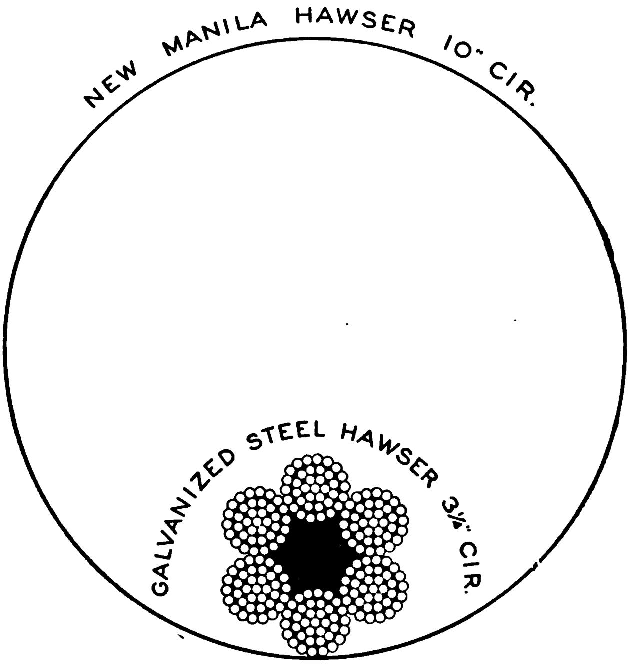
Two sizes are used. 5/8 in. are used on all portable drills, and ¾ in. on very heavy standard rigs.

Cut shows Right Hand Lay and is not used for Drilling Cables.

The breaking strain of 5/8 in. cable is 13.6 tons, allowable working strain 3¾ tons, weight per foot 0.62.

¾ inch cables have an approximate breaking strain of 19.4 tons; allowable working strain 3¾ tons; weight per foot 0.89 pounds.

The following cuts show the relative sizes of manila and steel ropes of equal strength.



---

## Splicing Steel Cables.

Splicing a steel cable is comparatively easy, even more so than splicing a soft laid rope.

The accompanying cuts are almost self explanatory and with the instructions given, the splice can be made with no difficulty whatever.

The tools required are a small marline-spike, nipping cutters, and either clamps or a small hemp rope sling with which to wrap around and untwist the rope. If a bench vise is accessible, it will be found very convenient for holding the rope.

In splicing rope, a certain length is used up in making the splice. An allowance of not less than 16 feet for ½-inch rope, and proportionately longer for larger sizes, must be added to the length of an endless rope, in ordering.

Having measured carefully the length the rope should be after splicing, and marked the points $M$ and $M'$ (*Fig.* 1), unlay the strands from each end $E$ and $E'$ to $M$ and $M'$, and cut off the hemp center at $M$ and $M'$, and then:

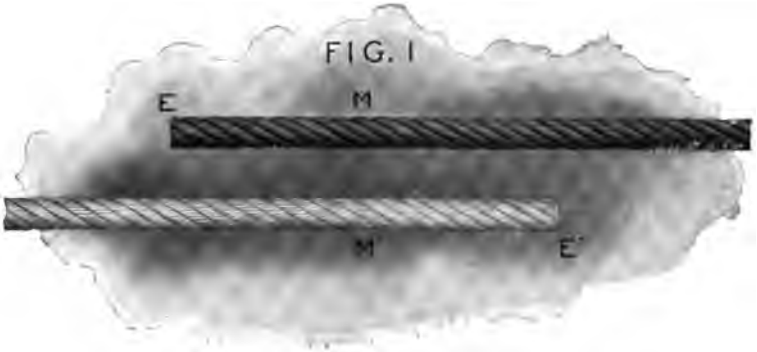


FIG. 1

FIRST. Interlock the six unlaid strands of each end alternately and draw them together, so that the points $M$ and $M'$ meet, as shown in *Fig.* 2.

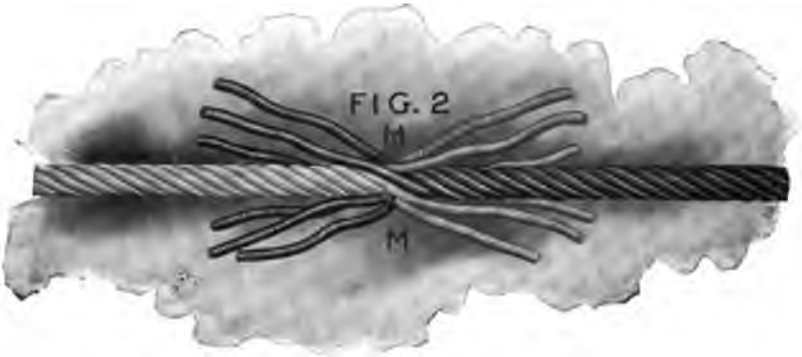


FIG. 2

SECOND. Unlay a strand from one end, and following the unlay closely, lay into the seam or groove it opens, the strand opposite it belonging to the other end of the rope, until within a length equal to three or four times the length of one lay of the rope, and cut the other strand to about the same length from the point of meeting, as shown at $A$ (*Fig.* 3).

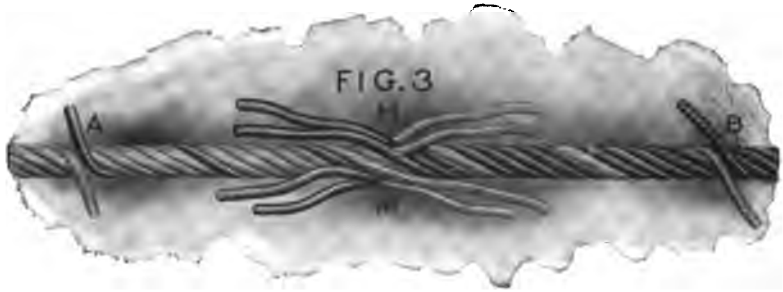


FIG. 3

THIRD. Unlay the adjacent strand in the opposite direction, and following the unlay closely, lay in its place the corresponding opposite strand, cutting the ends as described before at *B* (*Fig.* 3).

The four strands are now laid in place terminating at *A* and *B*, with the eight remaining at *M M'*, as shown in *Fig.* 3.

It will be well after laying each pair or strands to tie them temporarily at the points *A* and *B*.

Pursue the same course with the remaining four pairs of opposite strands, stopping each pair about eight or ten turns of the rope short of the preceding pair, and cutting the ends as before.

All the strands are now laid in their proper places with their respective ends passing each other, as shown in *Fig.* 4.

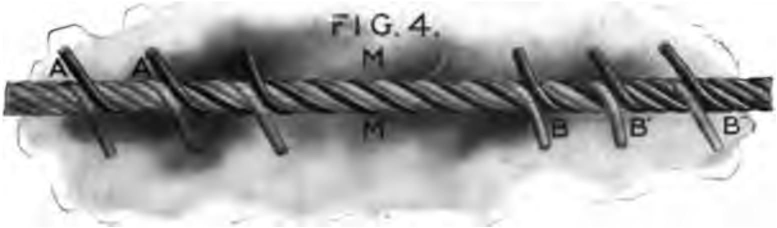


FIG. 4.

All methods of rope splicing are identical up to this point; their variety consists in the method of securing the ends. One good way is as follows:

Clamp the rope in a vise at a point to the left of *A* (*Fig.* 4), and by a hand clamp applied near *A*, open up the rope by untwisting sufficiently to cut the hemp core at *A*, and seizing it with the nippers, let your assistant draw it out slowly, you following it closely, crowding the strand in its place until it is all laid in. Cut the hemp core where the strand ends, and push the end back into its place. Remove the clamps and let the rope close together around it. Draw out the hemp core in the opposite direction and lay the other strand in the center of the rope in the same manner. Repeat the operation at the five remaining points, and hammer the rope lightly at the points where the ends pass each other at *A*, *A*, *B*, *B*, etc., with small wooden mallets, and the splice is complete, as shown in *Fig.* 5.

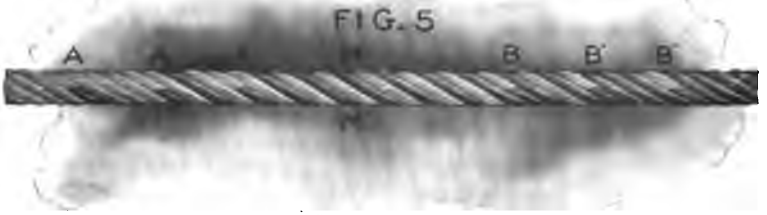
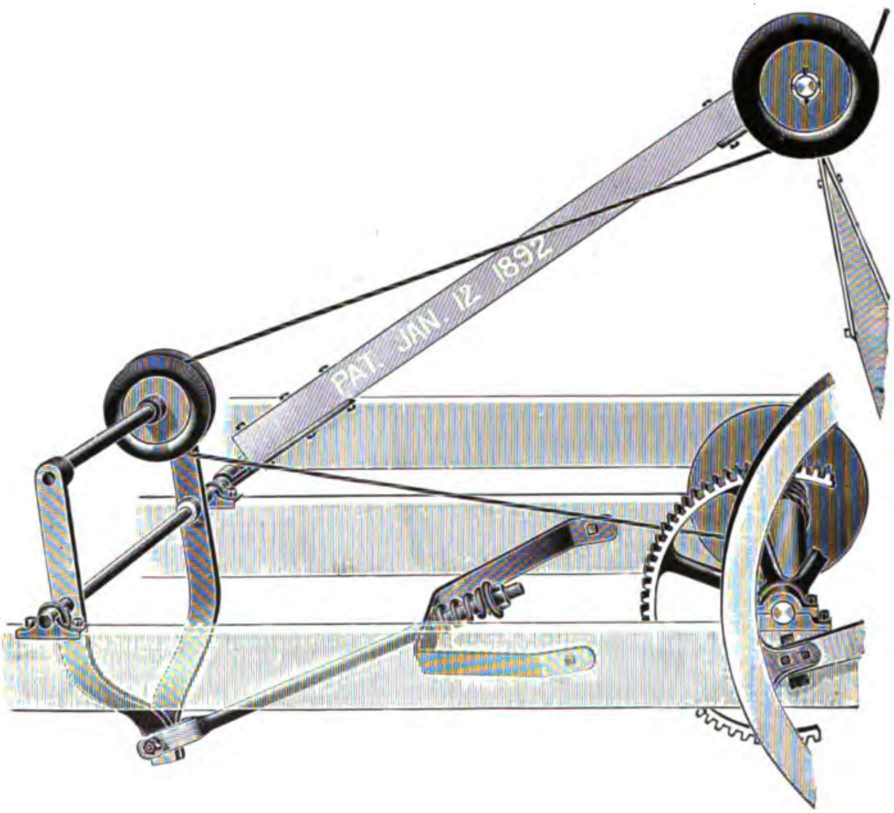


FIG. 5

## Wire Cable Used for Drilling.

Wire Cable is now being used quite extensively for drilling purposes. Especially is this so in the deep oil and gas fields when drilling has to be done through a large amount of water.

As wire cable has much less spring than Manila cable, it is necessary that some arrangement be made for giving it the requisite amount of spring unless the hole exceeds 600 feet in depth, in which case the wire line will be of sufficient length to furnish its own spring or stretch.



Wire Line Attachment.

On shallow holes it is the usual custom to use either a wire line attachment or else a piece of Manila rope between the drilling tools and the wire cable. If a piece of Manila is used it is fastened into the rope socket in the regular way and is fastened to the wire line with a chain and socket arrangement. If the wire attachment is used it is not necessary to insert the Manila line, as the wire cable can be fastened directly into the socket. In starting a hole, however, it is the usual custom to use Manila line exclusively inasmuch as the Manila is more flexible than the steel and thus is better adapted to pipe driving and works on top of the hole.

Besides the regular wire line attachment devices, there are several other mechanical methods of giving spring to the cable, among the most widely known being: Springs in rope socket, springs under spudder pulley, springs under crown pulley, and, on machines using walking beams, springs at end of beam and springs on sampson posts.

The writer's experience with wire drilling cable has been that it is best to drill down at least 300 feet before the wire line is put on. It is also best to shorten up the stroke somewhat and thus increase the number of strokes per minute.

The advantages of wire drilling cable can be summed up as follows:

- On deep holes will allow more strokes per minute.
- Will wear longer than Manila.
- Will give a better drop to the tools in a hole full of water.
- Will allow the drilling of a deep hole with a small machine, inasmuch as a machine capable of spooling 300 feet of 1⅝ inch Manila cable will spool at least 1500 feet of ⅝ inch steel line.

The disadvantages of the steel cable are:

- It puts a much heavier strain in the machine owing to the fact that the wire line has not stretch or spring enough to absorb the shock of the falling tools.
- It wears the sheaves rapidly.
- It makes a mean fishing job in case the line parts.

# PART VI.

## Pumping Equipments.

Owing to the fact that no two drilled wells are exactly the same in pumping capacity, height to which water will rise, and "strong points," it is necessary that the pumping equipments for different wells should be different.

If it is possible for the driller to do so, he should install the pumping equipment in all wells which he drills, not only for the money which he can make out of the business, but because he has an interest in seeing that the pumping plants are so installed that they will give the wells a chance to show up at their best.

Many drillers now handle pumps as a side line, and make quite a bit of money out of this end of the business alone. Not only does the driller make money out of the pumps, but what is of equal importance he knows that each well in which he has installed a pump can be depended upon to produce the amount of water which it is expected to produce.

A driller can now buy pumps in lots of one half dozen or more, direct from the manufacturers, and by so doing can buy them as cheaply as regular pump dealers. Thus, the driller can equip himself for this end of the business by a very small outlay.

If, however, you do not want to order the pumps yourself, you can probably make arrangements with some pump dealer, whereby you will be allowed a commission on all pump contracts which you secure.

Inasmuch as you have your machine derrick to work with, a pump can be put in in a very short time, and even if you do not get much for the work, it is time well spent, as the advertisement which you get by leaving your customer with not only a good well, but a perfect pumping plant is well worth the time spent.

In referring to the pump equipments above, the writer means the ordinary lift or force pumps as usually installed in farm wells and wells for private residences. In wells which are to be pumped for large capacity, the installing of pumping equipment often requires a knowledge of special machinery and appliances, and this you will not be expected to have, but there is no reason why you cannot acquaint yourself with the various kinds of deep well and large supply pumps, so as to have a working knowledge of them, and thus be able to talk intelligently upon the different systems of water elevation.

The catalogs now published by many pump manufacturers are extremely instructive, and it will pay you to send for all such publications, and to study them carefully.

The following instructions are only for the installing of lift and force pumps, as ordinarily used in drilled wells, but the general principles involved are applicable to all classes of pump installations.

The necessary parts of a pump are, going from the top downward: The Pump Stand, the Pump-rod or Piston-rod, the Discharge Pipe, the Cylinder, the Plunger and its Valve, the Check or Lower Valve and the Suction Pipe.

**Pump Standard**—The Pump Standard may be of any convenient design so long as it furnishes a handle to operate the pump-rod and a discharge spout for the water. Years ago, when all wells were dug wells, the wooden pump and the well sweep were used almost exclusively, but since the introduction of drilled wells and sanitary appliances, the iron pump has replaced to a great extent, its predecessors of poetical fame. For a pump standard to be satisfactory, it should be of sufficient strength and rigidity to stand firmly after being fastened to the platform, and if the pump is to be operated by hand it should have a brace extend from standard to platform, out in line with handle to prevent tilting of standard as handle is operated. This brace is not necessary if the pump is always to be operated by wind mill or pumping jack, as these appliances give a straight upward pull on the pump rod, and thus do not tend to sway the standard.

Type of Pump Standard as ordinarily furnished with Force Pump.

The platform surrounding the well should be of good thick oak planks, or else stone or cement, and the pump standard firmly fastened thereto.

If the water has to be lifted from considerable depth, say from 75 to 250 feet, and is to be pumped by hand, the handle of pump is usually weighted at the end, in order to counterbalance the weight of pump rods.

The length of stroke on a hand operated pump is usually 6 to 8 inches. When the pump is to be operated by power, the stroke varies according to the power used. On wind mills of average size, the stroke usually ranges from 6 to 10 inches. On some of the large irrigation wind mills of the west, the stroke of standard or pumping head ranges from 24 to 30 inches. These larger pumping heads cannot, of course, be called ordinary pump standards, and the writer has mentioned them only to show the development attained by modern wind mills.

Where the pump is of the force type, it is provided with a packing nut, either around pump rod at top of standard, or else at branch coupling on base of the short piece of pipe which fits on base of standard. As different kinds of force pumps are made with different arrangements for preventing the loss of pressure, no attempt will be made to go into details on this point.

You will note, in the reading of pump catalogs, that nearly all pumps are described as anti-freezing. This means that there is a small hole drilled into the short piece of pipe extending below base of standard, the hole being so drilled that it allows the water to run out of the discharge pipe, until the water is below the point reached by freezing temperature. If the pump extends directly into the drilled well, there is not much danger of freezing, if the freeze hole is placed three feet below the surface, but when the pump has a three-way connection, thus making it necessary to use an open sub-well the top of sub-well must be carefully covered in order to prevent freezing.

**Pump Rods**—Two kinds of pump rods are now in use. One the steel rods, and the other the wooden rods. Pipe is sometimes used for rods, but it is becoming more rare, and thus will not be discussed.

The best steel rods are made of cold drawn annealed steel, and are usually furnished in random lengths of approximately 20 feet.

Steel rods are connected together with couplings, and inasmuch as the rods are subjected to a thrust pressure, as well as pulling strain, the threads in coupling should extend clear through, so that the rods can be screwed into coupling until ends of rod meet. In order to do this it is, of course, necessary to cut a good long thread on ends of rods. Some concerns, in making couplings, use a tool that cuts a thread completely through from one end, and this is an advantage as it prevents cross threads, and thus assures the ends of rods meeting. Couplings as a rule are tapped 1-32 in. over-size, in order to allow the rod to enter full distance. In cutting threads on rods it should be borne in mind, that the hole in coupling is 1-32 in. over-size, for while it is desired to have the rods meet in center of coupling, they should set up rather tight, so that there will be no chance of the rods unscrewing, thus necessitating the removal of pump, in order to again connect them.

Owing to the fact that the rod couplings should come about even with the discharge pipe couplings, the rods should be so cut that they are approximately the same lengths as the corresponding pieces of discharge pipe. This applies also to wooden rods, and this point will be discussed under installing pumps.

Couplings for the metal rods are furnished in either malleable iron or brass. The brass is used because it does not rust fast to the rods, but if a good thick mixture of graphite and vaseline is used on the threads, the malleable couplings can be used, and no serious rusting of threads will result.

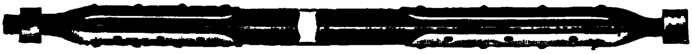
The following table gives the weight and number of threads per inch of the usual sizes of steel rods:

| Size | Weight per foot | No. threads to inch | Size | Weight per foot | No. threads to inch |
|---|---|---|---|---|---|
| ⅜ | .37 lbs. | 14 | ½ | .67 lbs. | 12 |
| 7/16 | .51 lbs. | 12 | ⅝ | 1.04 lbs. | 11 |

Owing to the fact that the pump rod which comes with the pump standard is often not of the same size as the rods used in well, it is necessary to have Reducer Couplings and the following table gives the sizes ordinarily carried in stock by pump dealers:

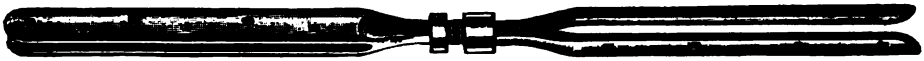
⅝ in. rod to ½ in. rod.
⅝ in. rod to 7/16 in. rod.
⅝ in. rod to ⅜ in. rod.
½ in. rod to 7/16 in. rod.
½ in. rod to ⅜ in. rod.
7/16 in. rod to ⅜ in. rod.
½ in. pipe to 7/16 in. rod.
½ in. pipe to ⅜ in. rod.
⅜ in. pipe to 7/16 in. rod.
⅜ in. pipe to ⅜ in. rod.
¼ in. pipe to 7/16 in. rod.
¼ in. pipe to ⅜ in. rod.

Wood pump rods are usually used, where the wells are of considerable depth, owing to the fact that the wood is lighter than water, and thus the rod weight is greatly reduced.



Wood Rod with Couplings.

The best wood rods are made of selected white ash, being coupled together by malleable iron or steel couplings, which are riveted on ends of rods. As wood rods are much larger than those of steel, it is necessary to have a larger discharge pipe in order not to decrease the capacity of pump.



Couplings used on Wood Rods.

Thus the installing of a pump with wood rods costs more, not alone for the rods, but for the extra large discharge pipe which it is necessary to use. However, the use of the large pipe is an advantage as it greatly reduces the friction of the ascending water, thus lessening the power required to operate the pump.

The following table gives the dimensions and capacities of different sizes of Octagon White Ash Rods:

| Size Rods Inches | Size Coupling Pin, inches | Size Pipe Inches | Size Cylinder adapted to Inches | Weight in lbs. per ft. of Rods in 20 ft lengths with couplings |
|---|---|---|---|---|
| 1⅛ | ⅝ | 2 | 1⅞ | .43 |
| 1⅜ | ⅞ | 2½ | 2¼ | .72 |
| 1⅝ | ⅞ | 3 | 2¾ | 1.02 |
| 1⅞ | 1 | 3½ | 3¼ | 1.53 |
| 2⅛ | 1⅛ | 4 | 3¾ | 1.86 |
| 2⅜ | 1⅛ | 4½ | 4¼ | 2.19 |

**Discharge Pipe**—On a lift pump the discharge pipe is the pipe connecting top of cylinder to bottom of pump standard.

On a force pump the discharge pipe has to be figured as made up of two units. One unit being the pipe connecting the top of cylinder to bottom of pump standard or branch coupling, the other unit being the pipe leading off from pump to point to which the water is to be forced.

The size of pipe to be used between the cylinder and pump standard depends upon the size of cylinder and also upon the size of pump rods. The following table gives sizes of discharge and suction pipes generally recommended for cylinders of different sizes, when metal pump rods are used:

| Diameter Cylinder, inches | 2 | 2¼ | 2½ | 2¾ | 3 | 3½ | 4 |
|---|---|---|---|---|---|---|---|
| Diameter Discharge Pipe, inches | 1¼ | 1¼ | 1¼ | 1¼ | 1¼ | 1½ | 2 |
| Diameter Suction Pipe, inches | 1¼ | 1¼ | 1¼ | 1¼ | 1¼ | 1½ | 2 |

The table shown on page 218 shows the size of discharge and suction pipe usually used when wooden pump rods are specified.

You will note from the table on page 218 that the internal diameter of pipe is slightly larger than the diameter of cylinder. This is for the purpose not only of making the pump work easier, but also for allowing the withdrawing of the pump plunger without the necessity of taking the pump out of the well. Thus, when it is desired to place new leathers on the plunger or make any repairs on same, the pump head or standard can be removed to one side and the rods with plunger can be pulled from hole without disturbing the rest of the equipment. This is not such an advantage in shallow wells, but it is of great importance on deep wells as the removal of several hundred feet of pipe from a well involves a large amount of work. While a pump having a discharge pipe as large or larger than the cylinder will pump easier than when a smaller pipe is used, still in ordinary pump installations it is customary to use a pipe of smaller diameter owing to its lower cost and also owing to the greater ease with which it is installed.

Pump manufacturers, in giving specifications of a pump, usually state that it is either tapped for a certain size of pipe, or that it is provided with a set-length pipe of certain size and as the discharge pipe should be of a size to fit the tapped opening or else of the same size as the set-length, you will know the size of discharge pipe to use on each type of standard.

If you are installing a force pump and the water is to be elevated to any considerable distance above the pump, the discharge pipe should be provided with an air chamber either in the pump or else along side of the pump. The air chamber forms a cushion and thus prevents sudden shocks or strains being thrown on the plunger.

As a rule galvanized pipe is used for discharge pipe, and inasmuch as the pipe is of small diameter and the water does not remain long in contact with the galvanized surface, it usually proves satisfactory. Where pipe 3 inches or larger in diameter is used, the regular black iron pipe is best.

When regular merchants pipe is used the diameter of the largest discharge pipe which will go into a well of given size can be found by figuring the external diameter of couplings. Coupling diameters will be found in table on page 38. If it is desired to have the largest possible discharge pipe, flush joint pipe or casing can be used. See description of flush joint on page 35.

If the drive pipe used in the well has been plugged and reamed, so as to be perfectly smooth inside, and the hole in rock (if the well has been made in rock) has been kept full size and true, a clearance of ⅛ in. between external diameter of discharge pipe couplings and inside of drive pipe will be ample.

If, however, the drive pipe is ordinary pipe, a clearance of ⅜ in. should be figured so as to allow for blisters or bumps.

The following tables will be of assistance in figuring capacities of, and strains in, discharge pipe of different sizes:

## Weight of Water Contained in One Foot Length of Pipe of Different Sizes.

| Size | Pounds | Size | Pounds | Size | Pounds |
|---|---|---|---|---|---|
| ½ | .086 | 2 | 1.372 | 4 | 5.488 |
| 1 | .343 | 2½ | 2.159 | 4½ | 6.956 |
| 1¼ | .537 | 3 | 3.087 | 5 | 8.575 |
| 1½ | .774 | 3½ | 4.214 | 6 | 12.348 |

To obtain the weight of water in pipe of any given length, multiply the weight per foot of water in that particular size of pipe as given in table, by the total length of pipe.

## Pressure of Water per Square Inch for Different Heights.

| Feet High | Pressure per Square Inch | Feet High | Pressure per Square Inch | Feet High | Pressure per Square Inch |
|---|---|---|---|---|---|
| 1 | .43 | 8 | 3.46 | 50 | 21.65 |
| 2 | .86 | 9 | 3.89 | 60 | 25.99 |
| 3 | 1.29 | 10 | 4.33 | 70 | 30.72 |
| 4 | 1.73 | 15 | 6.49 | 80 | 34.65 |
| 5 | 2.16 | 20 | 8.66 | 90 | 38.98 |
| 6 | 2.59 | 30 | 12.99 | 100 | 43.32 |
| 7 | 3.03 | 40 | 17.32 | ... | .... |

To obtain the pressure per square inch for any height not given in table, multiply the pressure per square inch in a pipe 1 foot high, which the table shows to be 0.43 pounds, by the total height of pipe.

# Friction of Water in Pipes.

**Friction loss, in pounds per square inch, for e .ch 100 feet of length of different sizes of clean iron pipe discharging given quantities of water per minute.**

| Gallons per Minute | SIZES OF PIPES, INSIDE DIAMETER, IN INCHES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ¾ | 1 | 1¼ | 1½ | .2 | 2½ | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 5 | 3.8 | 0.84 | 0.31 | 0.12 | 0.05 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 10 | 13.0 | 3.16 | 1.05 | 0.47 | 0.12 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 15 | 28.7 | 6.98 | 2.38 | 0.97 | 0.30 | 0.11 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 20 | 50.4 | 12.3 | 4.07 | 1.66 | 0.42 | 0.15 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 25 | 78.0 | 19.0 | 6.40 | 2.62 | 0.51 | 0.21 | 0.10 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 30 | ........ | 27.6 | 9.15 | 3.75 | 0.91 | 0.33 | 0.11 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 35 | ........ | 37.0 | 12.4 | 5.05 | 1.20 | 0.45 | 0.17 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 40 | ........ | 48.0 | 16.1 | 6.52 | 1.60 | 0.52 | 0.22 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 45 | ........ | ........ | 20.2 | 8.15 | 2.00 | 0.65 | 0.28 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 50 | ........ | ........ | 24.9 | 10.0 | 2.44 | 0.81 | 0.35 | 0.09 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 75 | ........ | ........ | 56.1 | 22.4 | 5.32 | 1.80 | 0.74 | 0.17 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 100 | ........ | ........ | ........ | 39.0 | 9.46 | 3.20 | 1.31 | 0.33 | 0.05 | ........ | ........ | ........ | ........ | ........ | ........ |
| 125 | ........ | ........ | ........ | ........ | 14.9 | 4.89 | 1.99 | 0.58 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 150 | ........ | ........ | ........ | ........ | 21.2 | 7.0 | 2.85 | 0.69 | 0.10 | ........ | ........ | ........ | ........ | ........ | ........ |
| 175 | ........ | ........ | ........ | ........ | 28.1 | 9.46 | 3.85 | 1.0 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 200 | ........ | ........ | ........ | ........ | 37.5 | 12.47 | 5.02 | 1.22 | 0.17 | ........ | ........ | ........ | ........ | ........ | ........ |
| 250 | ........ | ........ | ........ | ........ | ........ | 19.66 | 7.76 | 1.89 | 0.26 | 0.17 | 0.08 | 0.01 | ........ | ........ | ........ |
| 300 | ........ | ........ | ........ | ........ | ........ | 28.06 | 11.2 | 2.66 | 0.37 | 0.09 | 0.04 | ........ | ........ | ........ | ........ |
| 350 | ........ | ........ | ........ | ........ | ........ | ........ | 15.2 | 3.65 | 0.50 | 0.12 | 0.05 | 0.02 | ........ | ........ | ........ |
| 400 | ........ | ........ | ........ | ........ | ........ | ........ | 19.5 | 4.73 | 0.65 | 0.16 | 0.06 | ........ | ........ | ........ | ........ |
| 450 | ........ | ........ | ........ | ........ | ........ | ........ | 25.0 | 6.01 | 0.81 | 0.20 | 0.07 | 0.03 | ........ | ........ | ........ |
| 500 | ........ | ........ | ........ | ........ | ........ | ........ | 30.8 | 7.43 | 0.96 | 0.25 | 0.09 | 0.04 | 0.017 | 0.009 | 0.005 |
| 750 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 2.21 | 0.53 | 0.18 | 0.08 | ........ | ........ | ........ |
| 1000 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 3.88 | 0.94 | 0.32 | 0.13 | 0.062 | 0.036 | 0.020 |
| 1250 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 1.46 | 0.49 | 0.20 | ........ | ........ | ........ |
| 1500 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 2.09 | 0.70 | 0.29 | 0.135 | 0.071 | 0.040 |
| 1750 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.95 | 0.38 | ........ | ........ | ........ |
| 2000 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 1.23 | 0.49 | 0.234 | 0.123 | 0.071 |
| 2250 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.63 | ........ | ........ | ........ |
| 2500 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.77 | 0.362 | 0.188 | 0.107 |
| 3000 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 1.11 | 0.515 | 0.267 | 0.150 |
| 3500 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.697 | 0.365 | 0.204 |
| 4000 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.910 | 0.472 | 0.263 |
| 4500 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.593 | 0.333 |
| 5000 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 0.730 | 0.408 |
| Comparative Dsicharging' Power of Pipes | | 1 | 1.75 | 2.76 | 5.66 | 9.88 | 15.59 | 32. | 88.2 | 181. | 316.2 | 316.2 | 733 4 | 1024. | 1375. |

**Pump Cylinder**—The cylinder is probably the most important part of the whole pump equipment. It is the business end of the outfit, all other parts of pump equipment being assembled and arranged with a view towards making its operation as perfect as possible.

While a cylinder is spoken of as though it were a single thing, it is really composed of several parts which are designated as follows: Body or shell, top attachment or cap, bottom attachment or cap, plunger (consisting of cage, poppet valve, follower and leather packing), and the lower valve.

Cylinder shells as regularly furnished for drilled wells are of three general types, cast iron, brass lined and all brass.

The cast iron shell is cheapest in first cost and will prove very satisfactory if the water does not have to be elevated over 15 or 20 feet. When the lifts exceed 20 feet, a brass or brass lined cylinder should be used, owing to the fact that the iron surface wears the leathers of plunger very rapidly when the pump is worked against a heavy back pressure.

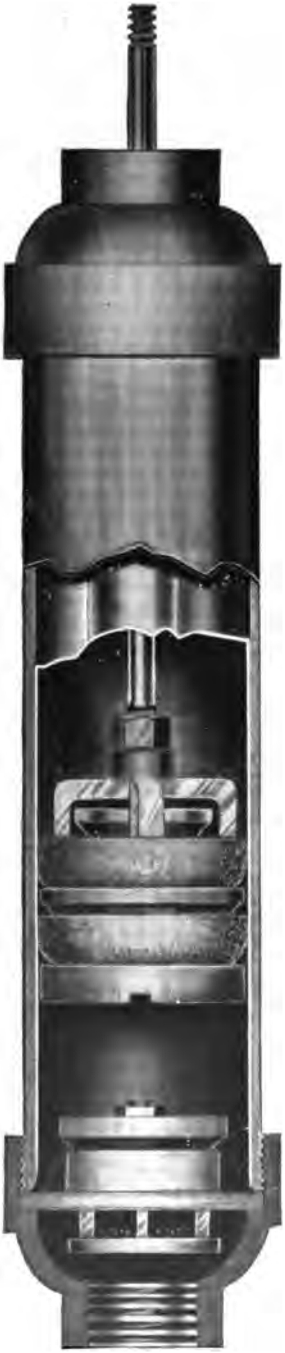
Iron cylinders are also unsatisfactory on account of their tendency to rust. In fact, in some wells with water having a high mineral content, it is absolutely impossible to use cylinders of iron, owing to the rapidity with which they are eaten out.

A brass lined shell makes a good strong cylinder and is very satisfactory if well made, but inasmuch as it is necessary to use outside caps or attachments, these cylinders can be used only in wells having a diameter considerably larger than the internal diameter of cylinder. This is a strong objection when it is desired to pump the well to its capacity. These same objections apply the all iron cylinder.

The all brass shell is made of seamless drawn brass and makes the most satisfactory all round cylinder. This style of shell can be furnished with either inside or outside top and bottom attachments, and thus a cylinder of the very largest possible size can be used in a well of given diameter. Another advantage of the all brass shell is that it is not affected by minerals present in ordinary well waters.

Another type of shell which is now coming into use quite extensively is a shell of wrought steel with brass lining and malleable top and bottom caps. This makes an extremely strong cylinder, its only objection being its outside top and bottom caps which reduce the size of cylinder which can be used in a given sized well.

This type of cylinder is sometimes provided with a drive point connection and driven into the ground, but as in has been proven conclusively by hundreds of tests, that shallow gravel water is not healthful, the writer does not recommend this style of well.

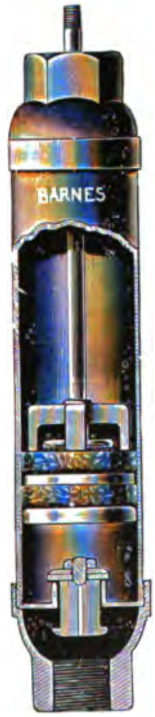


Brass Lined Cylinder showing construction of Plunger and Check Valve.

The following table gives the forms in which the different kinds of cylinders are to be obtained:

| All Cast Iron. | Cast Iron, Brass Lined. | Cast Steel, Brass Lined. | All Brass. |
|---|---|---|---|
| Outside caps only. | Outside caps only. | Outside caps only. | Outside caps.<br>Inside caps. |

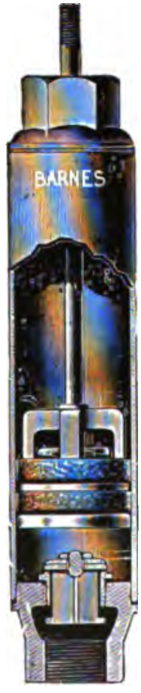
Besides the regular types of cylinder shells described above, the shell is sometims formed from the inside of the drive pipe of the well. Where the drive pipe is to be used for this purpose, a special piece of pipe having a smoothed inside surface should be inserted between two of the joints of pipe so that when the full line of pipe is driven the smoothed section will come at the right point. Inasmuch as nearly all wells in which this kind of shell is used are made in gravel, and inasmuch as in making gravel wells the lower end of pipe generally extends into the water bearing gravel stratum, it is the usual practice to put the smoothed section on the bottom of drive pipe. The check valve for this style of cylinder is inserted after the pipe has been driven, being fastened to the pipe with a special tool.



Cylinder with Outside Cap.

The type of cylinder just described is rarely used in wells exceeding three inches in diameter, its use being confined mainly to wells 2 to 2½ in. in size. The advantages which it possesses are, that the cylinder is the full size of pipe, thus allowing of pumping the well to the maximum, and also it is not necessary to use any extra discharge pipe, the drive pipe serving this purpose.

Its disadvantages are that the pipe wears rough, thus cutting out the leathers rapidly, and if anything gets wrong with the check valve and you cannot get it out, you stand a good chance of losing the well. Another trouble is that if the well pumps much sand, the pipe is soon cut so that the leathers do not hold the water.



Cylinder with Inside Cap.

However, as this style of well requires only the driving of 2 in. pipe, it can be installed at small cost and is very satisfactory where a moderate supply of water is desired.

When it is necessary to place the cylinder at any considerable depth, say 150 feet or greater, it is the usual practice to use a cylinder of considerable length, in order to obtain a long pumping stroke.

# Capacity of Different Sized Cylinders and Horse Power Required for Different Depths of Wells.

| Size of Cylinder, Inches | Length of Cylinder, Inches | Length of Stroke, Inches | Strokes per Minute | Gallons per Hour | Horse Power Required for 20 Feet Elevation | Horse Power Required for 50 Feet Elevation | Horse Power Required for 75 Feet Elevation | Horse Power Required for 100 Feet Elevation | Horse Power Required for 125 Feet Elevation | Horse Power Required for 150 Feet Elevation | Horse Power Required for 200 Feet Elevation | Size Suction Pipe, Inches | Size Discharge Pipe, Inches |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 10 | 6 | 40 | 196 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2 | 12 | 8 | 40 | 261 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2 | 14 | 10 | 40 | 326 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2 | 16 | 12 | 40 | 391 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¼ | 10 | 6 | 40 | 247 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¼ | 12 | 8 | 40 | 330 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¼ | 14 | 10 | 40 | 413 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¼ | 16 | 12 | 40 | 496 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2½ | 10 | 6 | 40 | 306 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2½ | 12 | 8 | 40 | 408 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2½ | 14 | 10 | 40 | 510 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2½ | 16 | 12 | 40 | 612 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 2¾ | 10 | 6 | 40 | 370 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¾ | 12 | 8 | 40 | 493 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 2¾ | 14 | 10 | 40 | 617 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 2¾ | 16 | 12 | 40 | 740 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 3 | 10 | 6 | 40 | 440 | .025 | .06 | .09 | .12 | .16 | .19 | .25 | 1¼ | 1¼ |
| 3 | 12 | 8 | 40 | 587 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 3 | 14 | 10 | 40 | 734 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 3 | 16 | 12 | 40 | 797 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1¼ | 1¼ |
| 3¼ | 10 | 6 | 40 | 517 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1½ | 1½ |
| 3¼ | 12 | 8 | 40 | 690 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1½ | 1½ |
| 3¼ | 14 | 10 | 40 | 862 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3¼ | 16 | 12 | 40 | 1035 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3½ | 10 | 6 | 40 | 577 | .05 | .12 | .19 | .25 | .31 | .37 | .5 | 1½ | 1½ |
| 3½ | 12 | 8 | 40 | 799 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3½ | 14 | 10 | 40 | 999 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3½ | 16 | 12 | 40 | 1288 | .1 | .25 | .37 | .5 | .62 | .75 | 1. | 1½ | 1½ |
| 3¾ | 10 | 6 | 40 | 689 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3¾ | 12 | 8 | 40 | 918 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 1½ | 1½ |
| 3¾ | 14 | 10 | 40 | 1148 | .1 | .25 | .37 | .5 | .62 | .75 | 1. | 1½ | 1½ |
| 3¾ | 16 | 12 | 40 | 1378 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 1½ | 1½ |
| 4 | 10 | 6 | 40 | 783 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 2 | 2 |
| 4 | 12 | 8 | 40 | 1044 | .1 | .25 | .37 | .5 | .62 | .75 | 1. | 2 | 2 |
| 4 | 14 | 10 | 40 | 1305 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 2 | 2 |
| 4 | 16 | 12 | 40 | 1566 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 2 | 2 |
| 4½ | 10 | 6 | 40 | 991 | .075 | .19 | .28 | .37 | .47 | .56 | .75 | 2½ | 2 |
| 4½ | 12 | 8 | 40 | 1321 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 2½ | 2 |
| 4½ | 14 | 10 | 40 | 1652 | .15 | .37 | .56 | .75 | .94 | 1.12 | 1.31 | 2½ | 2 |
| 4½ | 16 | 12 | 40 | 1982 | .175 | .44 | .66 | .87 | 1.08 | 1.31 | 1.53 | 2½ | 2 |
| 5 | 10 | 6 | 40 | 1224 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 3 | 2½ |
| 5 | 12 | 8 | 40 | 1332 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 3 | 2½ |
| 5 | 14 | 10 | 40 | 2040 | .175 | .44 | .66 | .87 | 1.08 | 1.31 | 1.58 | 3 | 2½ |
| 5 | 16 | 12 | 40 | 2448 | .2 | .5 | .75 | 1. | 1.25 | 1.50 | 2. | 3 | 2½ |
| 5½ | 10 | 6 | 40 | 1481 | .125 | .31 | .47 | .62 | .78 | .94 | 1.09 | 3 | 2½ |
| 5½ | 12 | 8 | 40 | 1947 | .175 | .44 | .66 | .87 | 1.08 | 1.31 | 1.53 | 3 | 2½ |
| 5½ | 14 | 10 | 40 | 2468 | .2 | .5 | .75 | 1. | 1.25 | 1.5 | 2. | 3 | 2½ |
| 5½ | 16 | 12 | 40 | 2962 | .25 | .62 | .94 | 1.25 | 1.56 | 1.87 | 2.19 | 3 | 2½ |
| 6 | 10 | 6 | 40 | 1762 | .175 | .44 | .66 | .87 | 1.08 | 1.31 | 1.53 | 4 | 4 |
| 6 | 12 | 8 | 40 | 2450 | .2 | .5 | .75 | 1. | 1.25 | 1.5 | 2. | 4 | 4 |
| 6 | 14 | 10 | 40 | 2937 | .25 | .62 | .94 | 1.25 | 1. 6 | 1.87 | 2.19 | 4 | 4 |
| 6 | 16 | 12 | 40 | 3525 | .3 | .75 | 1.12 | 1.5 | 1.87 | 2.25 | 3. | 4 | 4 |
| 7 | 10 | 6 | 40 | 2299 | .2 | .5 | .75 | 1. | 1.25 | 1.5 | 2. | 4½ | 4½ |
| 7 | 12 | 8 | 40 | 2798 | .25 | .62 | .94 | 1.25 | 1.56 | 1.87 | 2.19 | 4½ | 4½ |
| 7 | 14 | 10 | 40 | 3998 | .375 | .94 | 1.4 | 1.87 | 2.34 | 2.81 | 3.75 | 4½ | 4½ |
| 7 | 16 | 12 | 40 | 4798 | .45 | 1.12 | 1.68 | 2.25 | 2.81 | 3.37 | 4.5 | 4½ | 4½ |
| 8 | 10 | 6 | 40 | 3133 | .3 | .75 | 1.12 | 1.5 | 1.87 | 2.25 | 3. | 6 | 6 |
| 8 | 12 | 8 | 40 | 4177 | .375 | .94 | 1.4 | 1.87 | 2.34 | 2.81 | 3.75 | 6 | 6 |
| 8 | 14 | 10 | 40 | 5222 | .45 | 1.12 | 1.68 | 2.25 | 2.81 | 3.37 | 4.5 | 6 | 6 |
| 8 | 16 | 12 | 40 | 6266 | .5 | 1.25 | 1.87 | 2.5 | 3.12 | 3.75 | 5. | 6 | 6 |

The above table is theoretical—to get actual H. P. multiply by 2.

The power stated is approximated, as it is impossible to determine exactly the loss of power in friction. For wells from 150 to 200 feet deep, not over 20 strokes per minute is possible, unless very heavy machinery is used.

The capacity given in above table is based on 40 strokes per minute.

To find the capacity of any sized cylinder with less than 40 strokes per minute, deduct one fortieth part of the capacity given for each stroke less than 40 strokes per minute.

Inasmuch as a column of water 150 feet or more in height exerts a great pressure on the plunger, and inasmuch as water is absolutely incompressible, it is very necessary that the plunger be operated slowly in order to give the water column time to start without shock. By using the long cylinder, the water column is stopped and started less frequently than in the short cylinder, and thus the pumping capacity can be increased without putting additional stress on the pump standard or pump rods.

The following table shows the total downward pressure exerted on plungers of different diameters, on lifts of different heights, while on page 224 will be found table giving capacity of different sized cylinders and power required to operate same in wells of different depths.

### **Table of Plunger Loads, in Pounds.** (Estimated).

| Lift in Feet | DIAMETER OF CYLINDERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2½ | 3 | 3½ | 4 | 4½ | 5 | 6 | 7 | 8 | 9 | 10 |
| 50 | 129 | 180 | 240 | 307 | 384 | 562 | 775 | 956 | 1228 | 1377 | 1700 |
| 75 | 195 | 270 | 360 | 460 | 576 | 845 | 1165 | 1435 | 1840 | 2065 | 2550 |
| 100 | 260 | 360 | 480 | 615 | 770 | 1125 | 1550 | 1910 | 2455 | 2755 | 3400 |
| 125 | 320 | 450 | 600 | 770 | 960 | 1405 | 1940 | 2390 | 3070 | 3440 | 4250 |
| 150 | 385 | 540 | 720 | 920 | 1150 | 1985 | 2325 | 2870 | 3685 | 4130 | 5100 |
| 175 | 450 | 630 | 840 | 1075 | 1345 | 1970 | 2710 | 3350 | 4300 | 4820 | 5950 |
| 200 | 515 | 720 | 960 | 1230 | 1535 | 2250 | 3100 | 3825 | 4910 | 5510 | 6800 |
| 225 | 580 | 810 | 1080 | 1380 | 1730 | 2530 | 3490 | 4300 | 5525 | 6200 | 7650 |
| 250 | 645 | 900 | 1200 | 1535 | 1920 | 2810 | 3875 | 4780 | 6140 | 6885 | 8500 |
| 275 | 710 | 990 | 1320 | 1690 | 2110 | 3090 | 4260 | 5260 | 6755 | 7570 | 9350 |
| 300 | 775 | 1080 | 1440 | 1840 | 2305 | 3370 | 4650 | 5740 | 7370 | 8260 | 10200 |
| 350 | 900 | 1260 | 1680 | 2150 | 2690 | 3935 | 5425 | 6690 | 8600 | 9810 | 11900 |
| 400 | 1030 | 1440 | 1920 | 2455 | 3075 | 4500 | 6200 | 7650 | 9825 | 11015 | 13600 |
| 450 | 1160 | 1620 | 2160 | 2760 | 3460 | 5060 | 6975 | 8600 | 11000 | 12400 | 15300 |
| 500 | 1290 | 1800 | 2400 | 3070 | 3840 | 5620 | 7750 | 9560 | 12580 | 13770 | 17000 |
| 550 | 1415 | 1980 | 2640 | 3375 | 4225 | 6180 | 8520 | 10515 | 13510 | 15145 | 18700 |

In installing a pump in a drilled well, the cylinder should be placed so that it will be always below the water. By so placing it, there will never be any necessity for "priming" the pump, and besides the efficiency of pump will be the greatest, as the cylinder at each stroke will be entirely filled and this is something very hard to accomplish when the cylinder is filled by suction.

As previously explained, each well has its varying "strong points" and it should be the driller's aim to set the cylinder deep enough to pump from the desired "strong point" without lowering the water below the bottom of cylinder. Thus if 15 gallons per minute is the maximum amount to be pumped, the cylinder should be placed at a point giving 15 gallons per minute.

Some pump men, in order to be on the safe side, as they say, put the cylinder several feet below the proper point, claiming that it is best to be sure.

# Table Showing Amount of Water Discharged per Stroke by a Pump

### The Diameter of Cylinder and Length of Stroke Being Known.

| Diameter of Pump Cylinder in Inches | LENGTH OF STROKE IN INCHES, WITH CAPACITY PER STROKE IN GALLONS | | | | | | | | | | | Diameter and Areas of Circles | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | Gal. | Diameter of Circle (Pump Cylinder) in Inches | Area of Circle (Pump Cylinder) in Square Inches |
| 1 | .0034 | .0068 | .0102 | .0136 | .0170 | .0204 | .0238 | .0272 | .0340 | .0408 | " | 1 | .7854 |
| 1¼ | .0053 | .0106 | 0.159 | .0212 | .0266 | .0319 | .0372 | .0425 | .0531 | .0637 | " | 1¼ | 1.2271 |
| 1½ | .0076 | .0153 | 0.229 | .0306 | .0382 | .0459 | .0535 | .0612 | .0765 | .0918 | " | 1½ | 1.7671 |
| 1¾ | .0104 | .0208 | .0312 | .0416 | .0521 | .0625 | .0729 | .0833 | .1041 | .1249 | " | 1¾ | 2.4043 |
| 2 | .0136 | .0272 | .0408 | .0544 | .0680 | .0816 | .0952 | .1088 | .1360 | .1632 | " | 2 | 3.1416 |
| 2¼ | .0172 | .0344 | .0516 | .0688 | .0860 | .1033 | .1205 | .1377 | .1721 | .2071 | " | 2¼ | 3.9760 |
| 2½ | .0212 | .0425 | .0637 | .0850 | .1062 | .1275 | .1487 | .1700 | .2125 | .2550 | " | 2½ | 4.9087 |
| 2¾ | .0257 | .0514 | .0771 | .1028 | .1285 | .1543 | .1800 | .2057 | .2571 | .3085 | " | 2¾ | 5.9395 |
| 3 | .0306 | .0612 | .0918 | .1224 | .1530 | .1836 | .2142 | .2448 | .3060 | .3672 | " | 3 | 7.0686 |
| 3¼ | .0359 | .0719 | .1078 | .1438 | .1795 | .2156 | .2515 | .2875 | .3594 | .4313 | " | 3¼ | 8.2957 |
| 3½ | .0416 | .0833 | .1249 | .1666 | .2082 | .2499 | .2915 | .3332 | .4165 | .4998 | " | 3½ | 9.6211 |
| 3¾ | .0479 | .0957 | .1435 | .1914 | .2393 | .2871 | .3350 | .3828 | .4785 | .5743 | " | 3¾ | 11.044 |
| 4 | .0544 | .1088 | .1632 | .2176 | .2720 | .3264 | .3808 | .4352 | .5440 | .6528 | " | 4 | 12.566 |
| 4½ | .0688 | .1377 | .2065 | .2754 | .3442 | .4131 | .4819 | .5508 | .6885 | .8262 | " | 4½ | 15.904 |
| 5 | .0840 | .1700 | .2550 | .3400 | .4250 | .5100 | .5950 | .6800 | .8500 | 1.0200 | " | 5 | 19.635 |
| 5½ | .1028 | .2057 | .3085 | .4114 | .5142 | .6171 | .7199 | .8228 | 1.0285 | 1.2342 | " | 5½ | 23.758 |
| 6 | .1244 | .2448 | .3672 | .4896 | .6120 | .7344 | .8568 | .9792 | 1.2240 | 1.4688 | " | 6 | 28.274 |
| 7 | .1666 | .3332 | .4998 | .6664 | .8330 | .9996 | 1.1662 | 1.3328 | 1.6660 | 1.9992 | " | 7 | 38.484 |
| 8 | .2176 | .4352 | .6528 | .8704 | 1.0880 | 1.3056 | 1.5232 | 1.7408 | 2.1760 | 2.6112 | " | 8 | 50.285 |
| 9 | .2754 | .5508 | .8262 | 1.1016 | 1.3770 | 1.6524 | 1.9278 | 2.2032 | 2.7450 | 3.3048 | " | 9 | 63.617 |
| 10 | .3400 | .6800 | 1.0200 | 1.3600 | 1.7000 | 2.0400 | 2.3800 | 2.7200 | 3.4000 | 4.0800 | " | 10 | 78.540 |

In the above table the capacities are figured on single acting, one cylinder pumps only. For finding the capacity of Duplex and Triplex single and double acting pumps, and double acting hand pumps, increase the capacity accordingly. Thus a five inch single cylinder pump would have a capacity of .51 gallons per six inch stroke, a Duplex pump would be double this amount, a Triplex single acting pump three times, a Triplex double acting pump six times the amount, and so on.

**To obtain the capacity** of a pump with diameter of cylinder given in the table, but with a longer stroke than 12 inches (the longest stroke given in table), add or multiply the capacily to represent the required length of stroke.

**For instance:** The capacity of a cylinder with an 18 inch stroke would be the same as that (having the same diameter) of a 12 inch stroke cylinder, added to the capacity of a 6 inch stroke cylinder; or the same result may be obtained by multiplying the capacity of a cylinder with 6 inch stroke by 3.

**To obtain the amount of water discharged** per minute, multiply the capacity per stroke by the number of strokes per minute.

This, in the writer's opinion, is bad practice as it increases the length of column of water above the plunger, thus adding to the strain on the pump. While it is true that the column of water on outside of cylinder balances the column inside, for the distance which the cylinder is submerged, still by increasing the height of water above plunger, even though it is balanced by water on outside, the strain on pumping machinery is increased, owing to the larger total amount of water to be handled.

If it is desired to give the pump a margin of safety, it can be done by putting a short piece of suction pipe below the cylinder. By using the suction pipe, the available drawing area of the cylinder is increased without increasing the height of water above plunger, and even if by excessive pumping the water is drawn below the cylinder, it will, as soon as the excessive pumping is stopped, instantly rise to its old point above the cylinder.

In figuring on a pump for a certain well, the capacity of well must be taken into consideration and a pump of the proper capacity installed. Thus it would be a waste of money to install a pump of 25 gallons per minute capacity in a well which will supply only 10 gallons. Not only is money wasted in buying such a large pump, but what is worse still, the large pump will prove unsatisfactory owing to the fact that unless it is pumped very slowly, the well will be exhausted and the cylinder will "draw air."

On the other hand it is bad practice to put a small pumping equipment in a well which is expected to produce a large amount of water. If the equipment is too small it will be necessary to operate it above the proper speed and when this is done excessive wear results.

The table given on page 224 shows the number of gallons per hour pumped by cylinders of different sizes when run at the rate of 40 strokes per minute and while this number of strokes per minute is of course excessive for deep wells, it nevertheless serves as a basis from which to figure.

On page 226 will be found a table giving the number of gallons discharged at each stroke by cylinders of different sizes.

When wells are to be pumped by hand or by the ordinary 6 to 10 foot wind mills, there is another element besides capacity which enters into the calculation, this being the element of power.

As shown by the table on page 224 the amount of power required increases quite rapidly as the diameter of cylinder and depth of well increase.

In figuring on hand pump and on small wind pump installations, it is now the practice to make a sort of compromise between capacity wanted and power available, in order not to make the work too heavy.

While there is no inflexible rule to be followed, still experience seems to settle on the sizes given in the following table.

**Approximate Diameters of Cylinders for Hand and Wind Mill Pumps.**

| Depth of Well in feet (or less)........ | 25 | 35 | 50 | 75 | 100 | 150 | 200 |
|---|---|---|---|---|---|---|---|
| Largest Diameter of Cylinder in inches | 4 | 3½ | 3 | 2¾ | 2½ | 2¼ | 2 |
| Smallest Diameter of Suction and Discharge pipes in inches............ | 2 | 1½ | 1¼ | 1¼ | 1¼ | 1¼ | 1¼ |

Before placing a cylinder in a well, it should be taken apart and examined to see that all the parts are in working order and that no obstructions are present to interfere with their proper action.

A little time spent in this inspection may prevent the necessity of having to remove the pump equipment after same is installed.

In examining a cylinder see that the leathers are securely fastened in the plunger and that they fit snug against the shell. Examine the poppet valve in plunger to see that it seats properly and works freely and also inspect the lower or check valve. If all parts are in good order they can be replaced, the cups screwed onto shell and the cylinder is ready for the well.

**Suction Pipe**—In a drilled well a suction pipe, excepting under special condition, should play a very small part.

In the great majority of pump installations, the cylinder can be placed below the water and thus the only use of suction pipe is to give to the cylinder a margin of safety in case of excessive pumping. For this purpose a piece of pipe 12 to 15 feet long will be sufficient.

In those special cases where a suction pipe has to be used, you should be very careful to see that no holes are present in the pipe and also to see that where joints are made, the threads are liberally supplied with a "filler" and the joints well set up. Even a small leak in a suction pipe will decrease the efficiency of pumping plant very materially.

As pumping by suction depends upon producing a vacuum, or partial vacuum, into which the water is forced by atmospheric pressure, and inasmuch as this pressure decreases as the elevation above sea level increases, the efficiency of a suction pump depends not only upon the excellence of the construction of the pump, but also upon the geographical location of the well, in which it is to be used.

The outside limit for raising water vertically by suction is 33½ feet, and this can be done only at sea level and when a perfect vacuum is formed.

Ordinarily, 25 to 28 feet is the limit, but pump manufacturers as a rule, even on a first class job, do not recommend over 20 feet of perpendicular lift.

The following table gives the height to which it is possible to raise water by suction, at different elevations above sea level, if a perfect vacuum is formed and also gives the height it is safe to figure on for ordinary pumps.

### Barometric Pressures at Different Altitudes

### With Equivalent Head of Water and the Vertical Suction Lift of Pumps.

| Altitude | Barometric Pressue | Equivalent Head of Water | Practical Suction Lift of Pump |
|---|---|---|---|
| Sea Level.......... .......................... ...... | 14.70 lbs. per sq. in. | 33.95 ft. | 25 ft. |
| ¼ mile (1320 ft.) above sea level.... | 14.02 lbs. per sq. in. | 32.38 ft. | 24 ft. |
| ½ mile (2640 ft.) above sea level.... | 13.33 lbs. per sq. in. | 30.79 ft. | 23 ft. |
| ¾ mile (3960 ft.) above sea level.... | 12.66 lbs. per sq. in. | 29.24 ft. | 21 ft. |
| 1 mile (5280 ft.) above sea level.... | 12.02 lbs. per sq. in. | 27.76 ft. | 20 ft. |
| 1¼ miles (6600 ft.) above sea level.... | 11.42 lbs. per sq. in. | 26.38 ft. | 19 ft. |
| 1½ miles (7920 ft.) above sea level.... | 10.88 lbs. per sq. in. | 25.13 ft. | 18 ft. |
| 2 miles(10560 ft.) above sea level.... | 9.88 lbs. per sq. in. | 22.82 ft. | 17 ft. |

Some pump setters use a screen in the bottom of the suction pipe but this is of no advantage except when wells are made in sand or gravel or under special conditions, which points will be more thoroughly discussed under "Setting Screens."

## Installing the Pump.

As stated under "Pump Standard," "Discharge Pipe," "Pump Rods," "Pump Cylinder," and "Suction Pipe," it is necessary that the various parts making up a pump equipment be of proper size and proportion if the best results are to be obtained. Not only is the above true, but it is also necessary that the parts be properly assembled if the installation is to give the best satisfaction and the longest wear.

By referring to page 216 it will be noted that ordinary hand pump and wind pump standards give a stroke of from 6 to 10 inches. You will also note by referring to table on page 224 that cylinders are made about 4 inches longer than the stroke of the pump. This extra length of cylinder over stroke is for the purpose of giving a sufficient clearance both at top and bottom of cylinder in order to prevent the plunger from striking on either the up or down stroke.

In assembling and installing the pump it is very important that the length of the pump rod is such that the plunger has ample room both on the up and down stroke, and it is also important that the different sections of rods correspond in length with the different sections of discharge pipe, so that the couplings used to connect the pump will come about even with the couplings used on the discharge pipe. The advantage of this arrangement is that when the pump pipe is being put into the well or taken therefrom the pump rods can be connected or disconnecned without having to elevate the bottom of the different joints of pipe more than 3 or 4 feet above the surface of the ground. What has just been said applies only to those equipments using a discharge pipe smaller than the cylinder, as on the equipments having discharge pipes larger than the cylinder the pump rods can be put into place after the discharge pipe has been set.

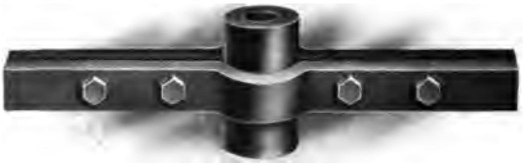
In connecting together the different sections of pump rods the instructions given on pages 217 and 218 should be followed out.

When screwing together the discharge pipe it should be remembered that it will be necessary to pull the pipe at some future time and thus the threads should be coated with a mixture of vaseline and graphite, which will not only assist in making a tight joint, but will also prevent the threads from rusting in the couplings thus making it impossible to unscrew the pipe without breaking the couplings. While it is the usual custom to use white lead on the joints, and while the white lead is excellent for making the joints tight, still the vaseline and graphite are equally effective and have the added advantage of preventing rust.

The graphite "dope" can be made by mixing about two parts of crude vaseline with one part of flake graphite.

If a long line of pipe is to be lowered into the well it can be most easily and safely handled by using casing elevators as described under "Re-Casing a Hole," and "Pulling Pipe."

Where a well requires the use of a long line of discharge pipe it is sometimes best to use a clamp for supporting the weight of the pipe after the full amount of pipe has been set, so that the strain will not fall upon the pump standard. The clamp can be made by any blacksmith being constructed as shown.



Pump Pipe Clamp.

## Well Curbing.

A drilled well when properly made will afford water of absolute purity as far as organic impurities are concerned, but unless the well is properly finished as well as made, it can become a disease breeding spot as easily as the old type of dug well.

The writer has seen a large number of good drilled wells condemned as unfit for use owing to the ignorance of health officers who figured that because the water of the wells was laden with disease germs, the wells should not be used. Had the health officers investigated conditions closer they would have found that the stream tapped by the well was affording water of absolute purity and that the foreign matter was coming in from the top. In order to make a well safe the drive pipe should extend 6 to 12 inches above the surface if the well is made on level ground, or even greater than 12 inches if the well is in a hollow or a depression. By thus extending the pipe it will make it impossible for surface water to enter from the top.

Another source of impurities is from the scrapings off of the feet of the users of the well. Unless the drive pipe extends 2 or 3 inches above the level of the pump platform, the scrapings are liable to be washed down with the first rain. Thus it is always a good plan to allow the pipe to project about 3 inches above the platform, and if the base of the pump standard is of such shape that it will not go down over the pipe, arrangements can be made for bolting the pump directly to the pipe.

Another plan being adopted by some drillers is to allow the pipe to extend 2 or 3 inches above the platform and then screw an iron cap over the pipe. The cap is provided with a threaded hole through which hole a threaded nipple, the same size as the discharge pipe, is screwed. The nipple is provided with a lock nut both above and below the cap and the discharge pipe is connected on below and the pipe of the pump standard is connected on above. This makes an absolutely air tight joint and thus precludes the possibility of any impurities entering.

The well cap proves very satisfactory in most instances, but there are some cases where the wells are in rock, that its use causes the water to become clouded. The writer has had this experience with two or three wells and the only explanation that he has ever been able to figure out is that the pumping lowers the water down to the "strong point" and this then causes a partial vacuum in the well which causes the fine sediment to rise. By taking off the caps the wells would at once pump clear but as soon as the caps were replaced the water would become cloudy.

One of the best platforms for a drilled well can be made of concrete. To fasten a pump to a concrete platform the bolts which hold it should be set in the concrete at the time the platform is made. This can be done by marking on a board of proper width the points where the bolts go through the pump base, then boring holes through the board and using this as a template. If the pump is of large size requiring the use of large bolts it may be necessary to place pieces of pipe 2 to 3 inches long having an inside diameter of about ½ inch larger than the bolts, around the bolts so that in case the bolts do not exactly line up with the holes in pump base they can be slightly driven over. If the short pieces of pipe are used the upper end of the pieces should come flush with the top of platform. The bolts should be of such length that they extend 4 to 5 inches below the lower end of short pieces of pipe.

As the concrete platforms are seldom over 4 inches thick and as this thickness is not sufficient for bedding the bolts, it is the usual custom to dig a hole 1½ feet square and 1 foot deep around the drive pipe and then fill this with concrete. This will not only make a good bedding for the bolts but will also prevent rusting of the drive pipe, as it will carry the concrete down below the point where the air and moisture have access to the pipe.

Owing to matters of convenience, also owing to fancied saving in cost as well as other reasons, customers often have drilled wells started in the bottom of dug wells. If the water of such wells is to be used for household purposes, it is absolutely necessary that the drive pipe be continued somewhat above the surface of the ground, for should the pipe be stopped down in the well, the drilled well water will be contaminated from the impurities of the dug well. Another danger which may arise from this type of well is that the water from the dug well will follow down along the outside of drive pipe and thus become mixed with the pure water. This danger is not so great if the well is drilled a hundred or more feet below the bottom of the old well, but it is almost sure to arise if the drilled well strikes its stream but a slight distance below the bottom of the dug well.

The safest course to follow is to fill up the old well so as not to allow the stale water to stand in it.

While of course the drill man would not be justified in going to the expense of making this fill simply to make sure of pure water, still he should try to convince his customer of the necessity of doing so.

## Sub-Wells for Wind Pumps.

In installing wind pump plants it is necessary in the large majority of cases to construct a sub-well 3 to 4 feet deep in order to provide space for the automatic pump control, also for the purpose of getting water lines down deep enough in the ground to be below freezing. A sub-well unless properly constructed may be the means of contaminating the pure water of the drilled well.

To make a good sub-well installation it is necessary to provide a water tight lining for the well and this is best accomplished by making the walls and bottom of concrete. The walls should be from 3 to 4 inches thick and the bottom from 4 to 5 inches thick. It is also necessary to run the walls 6 to 12 inches above the surface of the ground, to prevent the surface water from entering the sub-well. In making the bottom, the cement should be puddled around the drive pipe so that a tight union will be made at this point. The drive pipe should extend from 6 to 12 inches above the bottom of the sub-well so that any dirt which may collect in the sub-well will not be washed down in the drilled well in case water should accidentally enter from above.

If it is necessary to run one or more pipes through the walls of the sub-well, short pieces of pipe of the proper size should be inserted in the concrete at the proper points at the time the walls are made. The pieces of pipe should be 10 to 12 inches long for a wall 4 inches thick and should be threaded at both ends. In order to prevent the concrete from plugging the pipes, wooden plugs should be driven in the ends. The plugs can be removed when it is desired to connect up the water lines.

One thing which must be guarded against when a concrete sub-well is used and that is the accumulation of water in the bottom of the well. Inasmuch as the sub-well is water tight and will hold all water which enters, if water is allowed to accumulate it will finally reach a point when it will overflow into the drilled well. If it is possible to tap the sub-well with a drain, the accumulation of water need not be considered, but owing to the fact that a sub-well is usually deeper than drainage ditches, unless the well is in town where a sewer system is installed, it is rarely that drainage can be resorted to and thus all precautions must be used to prevent water from entering the sub-well.

The water which usually comes into the well is from the top, also from the freeze hole and leaks in the piping. The water can be kept from coming in at the top by raising the wall of the sub-well 10 to 12 inches above the surface and then using a water tight curbing. While of course it is impossible to make a platform absolutely tight, yet it can be so constructed that the water which does enter will be so small in amount that it will evaporate almost as rapidly as it comes in.

When the water comes from leaks in the pipe it is the result of faulty construction or bad workmanship, and the remedy is obvious—overhaul the job.

The leak from the freeze hole is however a necessity and in order to prevent this water from getting into the sub-well, arrangements should be made for conducting the water directly back into the drilled well. Some pump men do this by cutting the drainage pipe and inserting a tee and then running a small pipe from the tee back into the drilled well. Others obtain the same result by fastening a piece of tin around the pipe so placing the tin that the stream from the freeze hole is deflected into the top of the drive pipe. There are many methods of obtaining the same result but whatever the method used it should be so arranged that all of the water will go directly back into the drilled well.

## Heavy-Pump Installations.

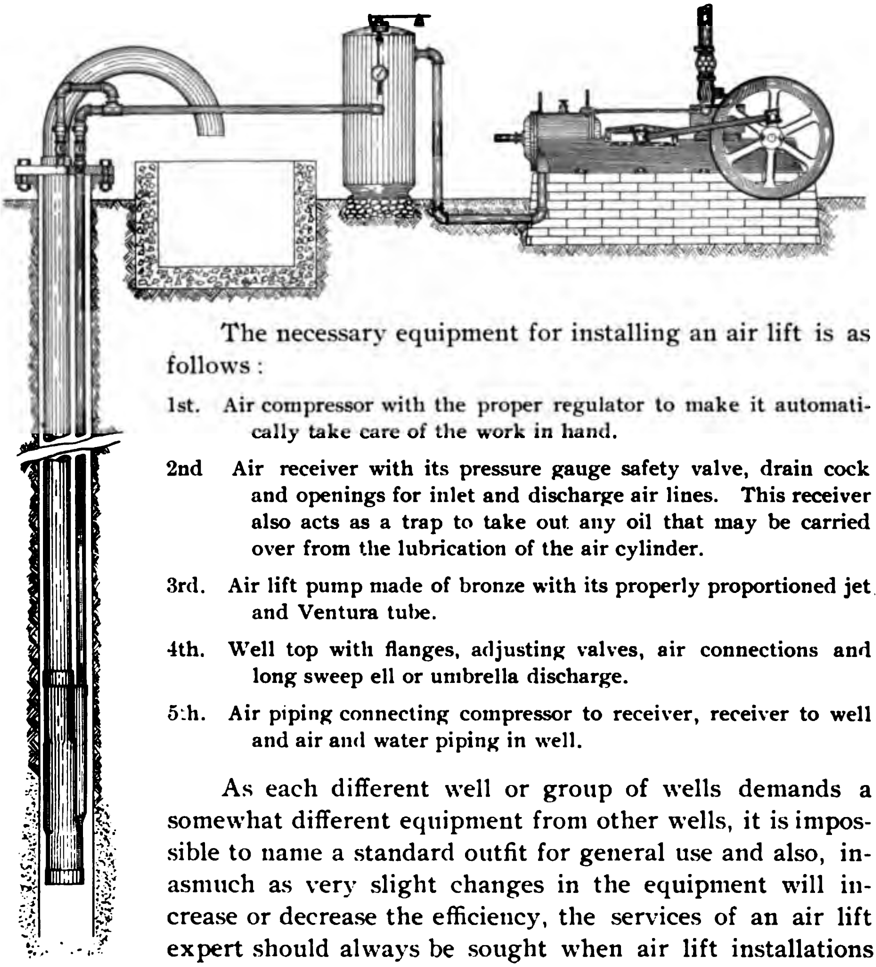
While the installing of heavy power driven pumps involves the same principles laid down in the foregoing pages, still owing to the heavy duty required of the big pumps, it is often necessary to use special appliances for taking care of special conditions. As stated on page 215 it will hardly be possible for a driller to acquaint himself with all the different types of deep well and heavy duty pumps, but if he will familiarize himself thoroughly with the principle of their installation he will, with the aid of the literature furnished by the pump manufacturers, be able to do the work successfully.

The writer would suggest however that before taking the contract for installing a heavy duty pump, that you make sure that you thoroughly understand the particular type of pumping equipment you have to handle as a "fall down" with the pump will not only give the pump a "black eye" but will also reflect on the well and the driller who drilled it. If there are any points about the equipment that you do not understand, write direct to the pump manufacturers and they will be glad to give you all the necessary information.

## The Air Lift.

Where several wells within a comparatively short distance of each other have to be pumped at the same time, the installation of a compressed air pumping plant will often show a marked saving in cost of operation over any type of pumping equipment.

The following cut shows the general plan of an air lift pumping outfit:



The necessary equipment for installing an air lift is as follows:

1st. Air compressor with the proper regulator to make it automatically take care of the work in hand.

2nd Air receiver with its pressure gauge safety valve, drain cock and openings for inlet and discharge air lines. This receiver also acts as a trap to take out any oil that may be carried over from the lubrication of the air cylinder.

3rd. Air lift pump made of bronze with its properly proportioned jet and Ventura tube.

4th. Well top with flanges, adjusting valves, air connections and long sweep ell or umbrella discharge.

5th. Air piping connecting compressor to receiver, receiver to well and air and water piping in well.

As each different well or group of wells demands a somewhat different equipment from other wells, it is impossible to name a standard outfit for general use and also, inasmuch as very slight changes in the equipment will increase or decrease the efficiency, the services of an air lift expert should always be sought when air lift installations are to be made.

For further information regarding the installing of this comparatively modern method of pumping, the writer would suggest that you consult the publications of various air lift equipment manufacturers.

## Pneumatic Displacement Pump.

This pump consists of two tanks being submerged or so placed as to fill by gravity. In connection with these tanks is an automatic switch controlling the passage of air to the tanks so that when the water has been forced out of one tank the air is switched to the full tank and the air in the emptied tank exhausted to the atmosphere which then refills with water by gravity.

The especial province of this pump is to handle water at a distance from the power plant, as all that is needed is one line to carry the air to the pump and another to bring the water back.

This pump is automatic in its action and requires practically no attention as the fluid being pumped comes in contact with no moving parts other than the inlet and discharge check valves.

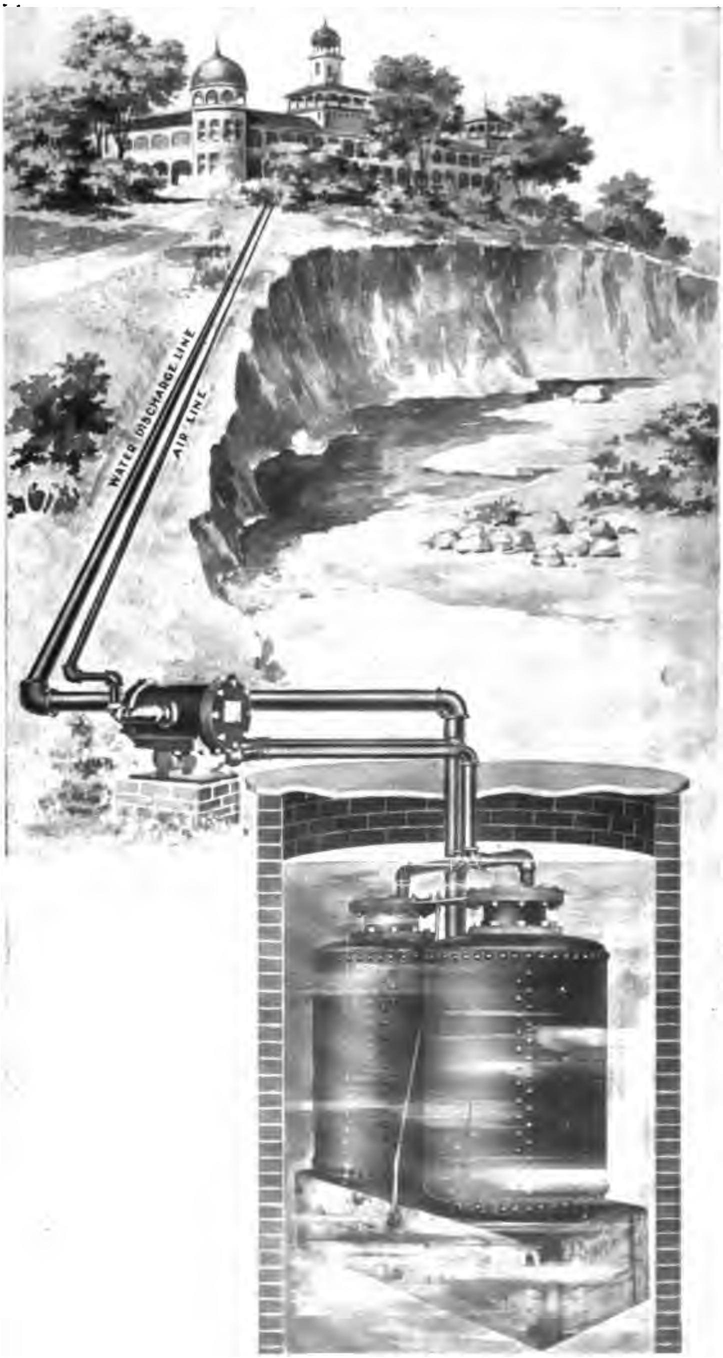
Any number of these pumps can be operated from a single air line and made entirely automatic.

Another use of this pump is to maintain a constant pressure upon a system of piping as in small towns, factories and office buildings, and can be so arranged with air lift in a well and governed compressor, (steam or electric), that the whole system can be automatically stopped, started and controlled by the water user. An efficiency of from 25 to 40 per cent can be obtained with the additional advantage that the water never comes in contact with any moving parts from well to consumer.

## Water Table.

| | |
|---|---|
| A cubic inch of water weighs | .03617 lbs. |
| A cubic foot of water weighs | 62.46 lbs,=62½ lbs. |
| A gallon of water weighs | 8.355 lbs.= 8⅓ lbs. |
| A U. S. gallon of water contains | 231 cu. in. |
| An English gallon of water contains | 277¼ cu. in. |
| A cubic foot of water contains | 1728 cu. in. |
| A cubic foot of water contains | 7.4805 gals.=7½ gals. |

A "miner's inch" of water approximately equals a supply of 12 U. S. gallons per minute.



General Equipment for Compressed Air Displacement Pump.

# PART VII.

## The Use of a Walking Beam.

Machines which are built for drilling deep holes are usually equipped with a walking beam as well as a spudding device, for operating the tools. Even on comparatively shallow holes, when the material to be drilled is extremely hard, it is usually best to have a walking beam and hook it on after a depth of 100 to 150 feet has been reached.

In the descriptions and instructions so far given, the writer has refrained from discussing the use of the walking beam owing to the fact that he did not want to confuse the reader by making constant reference to two types of mechanisms for imparting motion to the drilling tools. While all of the instructions so far given have been made with special reference to a spudding device, still they are equally applicable to the walking beam, it being borne in mind, of course, that the beam is primarily a deep hole device or one for rock work.

The advantages of a walking beam over a spudding device for handling rock drilling are, that it gives a better stroke to the tools and it is easier on the drilling cable.

However, to get a better stroke out of a walking beam, than can be gotten with a good spudding device, it is necessary that the hole be at least 300 feet deep and even at this depth, unless the rock is extremely hard, the writer prefers the spudder when light tools are being run. While with a beam it may be possible to get a slightly better stroke at a depth of 300 feet, still the spudder offers advantages in simplicity, ease of handling and speed in changing from drilling to hoisting, which will more than equalize matters. Thus it would be the writer's advice that when the holes to be drilled do not exceed 300 to 350 feet in depth, and when light tools are to be run and when the rock to be drilled is not of extreme hardness, that the spudding device be used exclusively. This advice is based on the assumption that manila drilling cable is the type of cable used as with wire drilling cable the capacity of the spudder is greatly increased, it being possible to satisfactorily handle drill work up to a depth of 1200 to 1500 feet without resorting to the use of a walking beam.

The advantage of a walking beam in regard to economy is due to the fact that the beam hooks directly onto the cable and thus does away with sheave wear on the rope; also the wear which results from the friction of the rope on the drum. This rope wear does not become a serious item under ordinary drilling conditions, but when extremely hard rock is encountered, it holds the tools at one place a length of time sufficient to burn out the cable on the sheaves over which it works.

From what has been said above it will be noted that a walking beam is primarily a deep well drilling device, but that it may also show advantages in shallow holes when extremely hard formations such as granite or trap rock have to be penetrated.

There are now on the market two general types of walking beams, namely, the Grasshopper Beam and the Standard Beam.

The main difference between these two types of beams is that the grasshopper beam is hinged at one end, while the standard is hinged in the center. As a rule the grasshopper beam is made up double, that is, there are two beams, one on either side of the machine, the two beams being provided with separate pitmans and cranks which are so adjusted as to give the same throw to the beams. Owing to the fact that all grasshopper beam machines use the beams for spudding as well as drilling, the use of the double arms is an advantage inasmuch as it allows ample room for handling the spudding work, pipe driving, etc.

At the present time there are three types of the Standard Beam, these being the Straight Beam, the Segment Beam and tho Double Standard Beam.

The Standard Beam is the type used on oil well outfits known as Standard Rigs. The standard beam is also used on several different types of deep well portable outfits.

The Segment Beam is usually much shorter than a standard beam and is provided with a Segment or Horsehead at its outer end. The segment is cut on an arc of such radius that the drilling cable always comes in line with the center of the hole.

The Double Standard Beam is made up the same as a Standard Beam excepting that there are two arms on beams instead of one. This style of beam is used only on portable rigs, but for this kind of work it is particularly well adapted.

The advantages and disadvantages of the beams listed above are as follows:

## The Grasshopper Beam.

| ADVANTAGES | DISADVANTAGES |
|---|---|
| The changing from spudding to drilling can be quickly done. Distributes the strain evenly upon the frame of the machine. The beams are used for spudding as well as drilling, thus reducing the number of parts necessary to make up a machine. | Does not give as good a stroke as a center hinged or standard beam.<br>When drilling, the strain on the pitmans is a push instead of a pull, thus making it necessary to use guide blocks which rub against the beams causing excessive wear, besides consuming considerable power. |

## Standard Beam.

ADVANTAGES

On standard rigs is to be preferred to any other type of beam as it can be made of sufficient length and size to give the best stroke and have the greatest strength.

On portable rigs gives a good stroke to the tools, but is hard on machines.

DISADVANTAGES

Has no disadvantages on standard rigs, but on portable outfits it throws a heavy side strain or twist on the whole machine frame also upon the machinery upon the frame. This is due to the fact that the sampson post has to be set on one side of the machine as the beam must cross the frame at an angle in order to be out of the way of drill rope, sand line and spudding device

## The Segment Beam.

Owing to the shortness of a segment beam it need not be made as heavy or cumbersome as a standard beam.

The segment on the end of the beam keeps the rope in the center of the hole, thus reducing wear on the cable.

The sampson post can be placed midway between the main sills thus evening up the strain on the frame and doing away with all racking of the machinery.

About the only disadvantages the writer has ever found with this type of beam is in the handling of the temper screw. This is caused by the fact that the upper half of the frame is cut off, being replaced by chains working over the segment, thus making it impossible to use an elevator on the screw. However, with a little practice, a driller can hoist the screw by leaving the rope clamps on the rope so that this disadvantage is more apparent than real. It has been said that a segment beam, owing to its shortness, runs somewhat heavier and while this is true if the beam is made extremely short, still the writer's experience has been that a segment beam whose length does not fall under 8 or 10 feet will handle with as little power as a longer one.

## The Double Standard Beam.

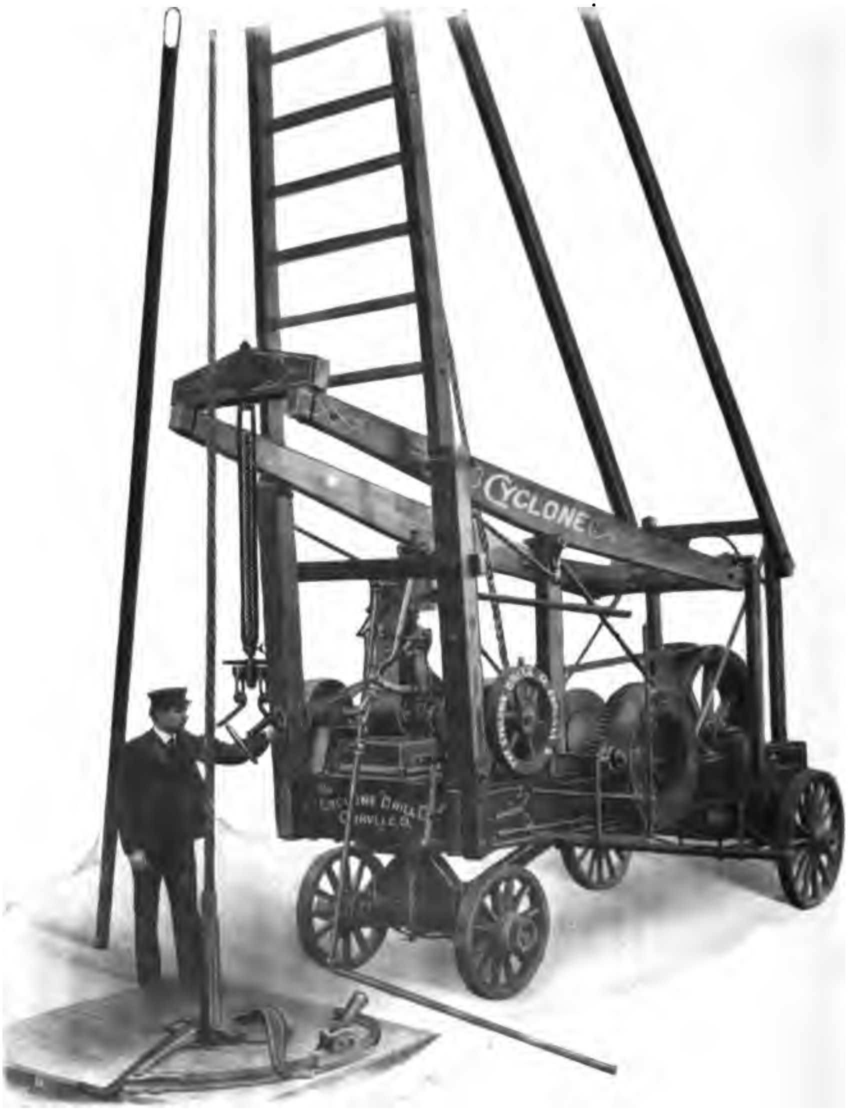
By having two beams, two sampson posts can be used, one being placed on either sill and thus the strains upon the machine are evenly balanced.

As the beams can be used for spudding as well as drilling it is unnecessary to have a separate spudding device and thus the machine is less cumbersome.

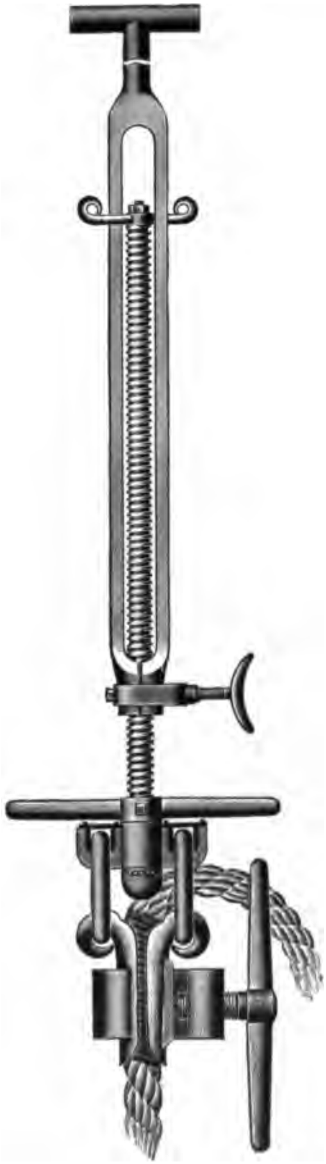
It requires but a short time to change from spudding to drilling.

This style of beam has no disadvantages that the writer knows of except that if the beams are made of unseasoned wood they are liable to warp, thus causing them to bind. However, as this trouble is caused by poor manufacturing and not due to the principle of construction, it cannot be argued against this type of beam.

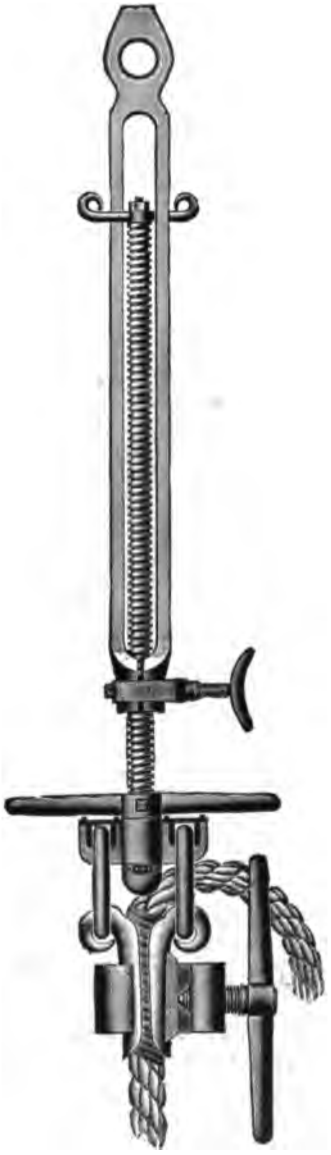
The appliance used to connect a walking beam to the drill rope is known as a temper screw. All temper screws are made on the same gen-



A deep well type of drilling machine using the Double Standard Beams. The temper screw is hung from a cross bar which is fastened to the outer ends of beams. When spudding, the cross bar is slipped off and laid to one side.



Temper Screw with Tee Head.

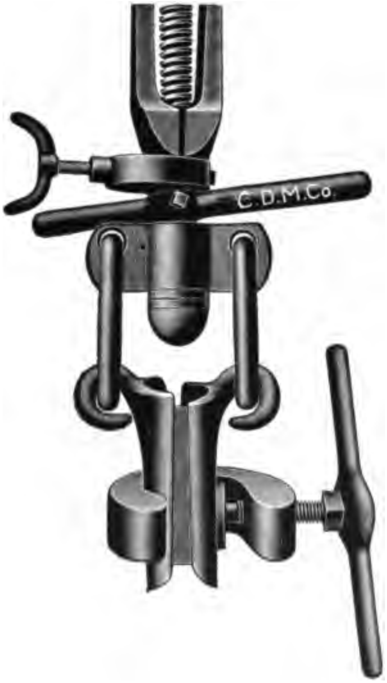


Temper Screw with Eye.

eral principle, that is, they are provided with a frame, main screw and a swiveled clamping device for coupling onto the rope. The cuts shown herewith give a clear idea of the most universally used types. The cut on the following page gives a more detailed view of the lower part of the appliance.

In using a walking beam and a temper screw, the tools are lowered into the hole until they come within a short distance of the bottom, this distance depending upon depth of hole and weight of tools. Next the pitman is placed on the crank pin and the crank thrown to the high point, thus throwing the temper screw on the down stroke. If it has not already been done, the main screw is now shoved up until the cross bar on the screw comes up against the split nut.

Next wrap the drill cable at a point opposite the rope clamp with a "Wrapper," then place the clamps over the wrapper and draw them up as tight as possible with the C screw handle. Now slack off the cable until the full weight is supported by the temper screw and then pull down 10 to 15 feet of additional slack so that the motion of the beam will not cause the cable above the clamps to lash around.



Lower part of Temper Screw.

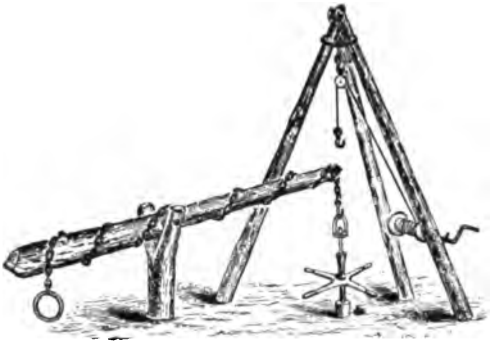
To make the "Wrapper" or the "Cat" as it is often called by the drillers, cut off a piece of cable about 4 to 5 feet long and take out one of the three main plys. Unwind this ply until all the strands are separated. To place the wrapper around the cable, begin an inch or two below the lower end of rope clamps and wrap upward for a couple of inches above the top of clamps. Now wrap downward but do not go quite to the base of lower wrap. Repeat these operations each time keeping a little further from the base of wrap, until all of the wrap is on the cable. If the work has been properly done there will be a pear shaped mass of rope with the small end of the pear downward, opposite the rope clamps.

The speed to run a walking beam, also the length of stroke, depends upon the depth of hole and this will have to be learned by experience. The general rule, however, is to run the beam at such speed as will give the tools a quick, snappy motion.

A walking beam and temper screw can be used for handling wire line as well as manila cable, but to do this it is necessary to use a specially constructed set of rope clamps.

# PART VIII.

## Hollow Rod Tools.



Spring Pole Surface Equipment

The hollow rod system of drilling is the outgrowth or evolution of the old spring pole and solid rod system. The cut herewith shown gives an idea of the surface equipment of a spring pole outfit. The drilling tools proper consisted of wooden rods coupled together and carrying at the lower end a chisel bit. The couplings used for connecting the rods were somewhat similar to the pump rod couplings shown on page 218.

It is impossible to trace when this system of drilling was first introduced into this country, but records of wells drilled in France and England show that it is a special adaptation of methods employed in those countries as far back as 1740.

In this country the spring pole was finally superseded by more perfect means for reciprocating the rods and along about 1856 or 1857, Jesse N. Bolles, a driller of Pennsylvania, introduced the use of hollow drill rods in place of the solid wooden rods. The tools as built by Mr. Bolles were constructed with a system of valves located in the rods, these valves serving to pump the cuttings out of the hole as the drilling proceeded. Thus originated the self pumping tools, or as they are now generally termed, the hydraulic tools.

Later, somewhere about 1880, a Mr. W. C. Wells found that by removing the valves from the Bolles equipment and then forcing a stream of water down through the rods, he could handle drill work through sand and certain other unconsolidated deposits to much better advantage than could be handled by the older method. Thus originated a new system of drilling and to distinguish this new system from the hydraulic, it was called the jetting method.

While a somewhat similar method of drilling was patented in England in the year 1844, by an Englishman named Beart, still Mr. Wells deserves full credit for his work, as records show that the improvements which he worked out were the results of original experiments and that he had no knowledge of the Beart system which was but slightly used in England and was abandoned entirely within two or three years after the patent was secured.

While there are other methods of drilling which use hollow drill rods in their operation, these methods being known as rotary, core, etc., still in this discussion, which we have headed "Hollow Rod Tools," we will confine ourselves solely to the hydraulic and jetting systems as probably 95 to 98 per cent. of all water wells drilled with hollow rod tools are handled by one or the other of these two types of outfits.

For handling certain classes of drill work the hollow rod tools possess undoubted advantages over cable tools, these advantages being as follows:

With hollow rod tools, holes as small as 2 inches in diameter can be rapidly drilled, and as small diameter casing can be purchased much cheaper than the larger sizes, it thus makes it possible to do drill work at a lower rate per foot.

Drilling with rod tools is cheaper than with cable tools inasmuch as the cable does not go into the hole and thus the cable expense is much less.

The expense of keeping up a set of tools, also the repairs for the same are much less than for cable tools.

Drilling with rod tools is safer for the reason that the rods are continuous from the bottom to the top of the hole.

When drilling holes 2 to 3½ inches in diameter where the holes to be drilled do not penetrate a large amount of hard rock or, when drilling holes as large as 5 or 6 inches in diameter through unconsolidated deposits when the jetting process is used, much better time can be made with the rod tools, than can be made with cable tools.

In case fishing jobs arise they are easier to handle with rod tools.

It requires less power to operate rod tools owing to the shorter strokes used, and thus a machine which cannot handle cable tools deeper than 300 feet will have ample power, and if properly made, will be of ample size for handling rod tools to the depth of from 800 to 1000 feet.

The above are the main advantages, but others will be mentioned as we proceed with the instructions and descriptive matter.

The successful performance of hollow rod drilling tools when used by either the hydraulic or jetting methods depends quite a bit upon the type of machine employed to operate them. While of course some hole can be made with the crudest of surface equipment as evidenced by the fact that the spring pole was primarily used, still modern drilling practice has shown that there are certain requirements demanded of the drilling machine proper, if the most rapid and satisfactory work is to be done with rod tools. First and foremost of these requirements is a good spudding device, second, a positive means for feeding off the drill rope and third, a sure and rapid method of lowering and hoisting the drill rods. There are of course many other details that can be worked out which will be of convenience to the driller in making hole, but they are of secondary, rather than of primary importance.

The requirements of a good spudder are as follows:

It should be so arranged that a stroke of from 6 to 18 or 20 inches can be secured.

It should be so constructed that a speed of from 40 to 100 or 120 strokes per minute can be maintained without straining or racking the machine.

The arrangement of the spudder parts in relation to the remainder of the machine should be such that wear on the drill rope is brought down to the lowest point.

The action of the spudder should be such that the tools are always under positive control.

The spudder should be so arranged and proportioned as to give a quick drop and yet have a comparatively slow motion in lifting the tools.

The spudder should run without thump or jar.

The reasons for demanding the above requirements of a spudder are as follows:

The stroke must be capable of adjustment on account of the fact that, as the hole gets deeper the weight of the rods becomes greater and thus the stroke must be shortened up to prevent the force of the blow from kinking the rods or telescoping the joints. If the stroke is kept at the proper length, to correspond with the depth of hole, much greater drilling speed can be made than if one length of stroke is used for all depths of hole. Thus in beginning a hole it is best to give the tools as long a stroke as they will stand and then as the hole deepens, shorten up the stroke and run the tools at higher speed.

Another advantage obtained by shortening the stroke is that the strain on the machine and power plant is reduced in proportion to the amount the stroke is made less, and thus a machine having an adjustable stroke will be able to handle a deeper hole than one of the same size having but one length of stroke. Of course, if the latter machine is provided with a crank giving a stroke as short as the shortest stroke on the other machine, it will be able to drill to the same depth, but its speed on the first part of the hole, owing to the short stroke used, will be very slow in comparison.

As a rule, the wells in any particular section pass through practically the same geological strata and deposits so that a driller operating in that locality soon learns the proper length of stroke to use for making the most headway in the different formations. If the drilling machine used has only one length of stroke, the driller is forced to use this length whether or not it is the most advantageous.

It has been the writer's experience that the best lengths of strokes are about 6, 10, 14 and 18 inches. It is not very often that an eighteen inch stroke is used for drilling but it comes in handy on hard pipe driving and pipe pulling jobs.

The next point to consider in regard to a spudder is whether or not it is possible to so operate it that the tools are always under positive control. This feature of positive control is even more important than an adjustable stroke just discussed, for a one-stroke-positive-control spudder is more efficient than a multiple-stroke spudder of the uncontrolled type.

What is here meant by an uncontrolled spudder is one which operates by lifting the tools to a certain height and then by means of a trip or trigger disconnects the power from the spudding arm and allows the tools to fall "dead" upon the bottom of the hole. The cam and treadle is at the present time the most generally used of all the different types of uncontrolled spudders.

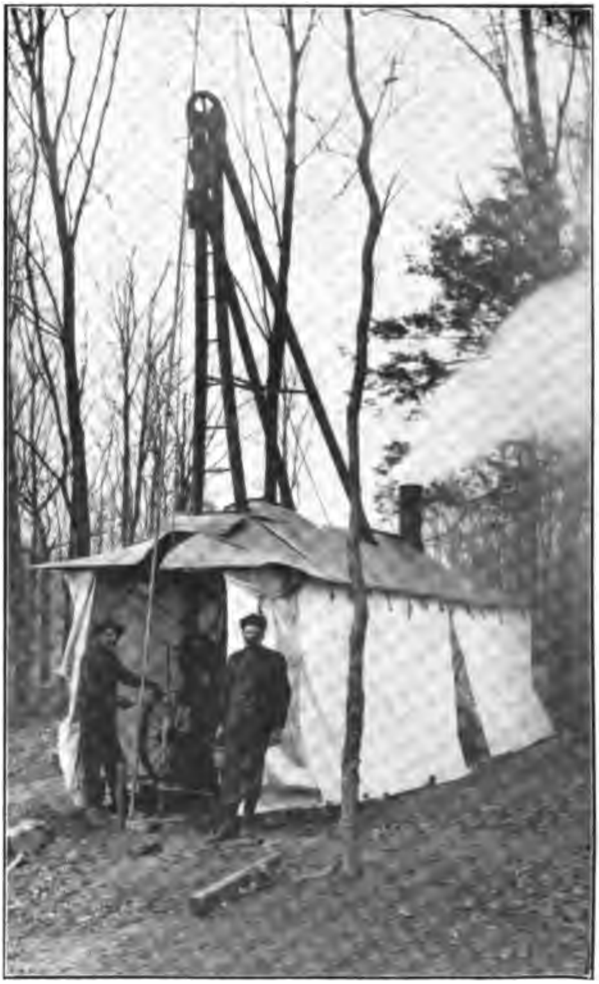
The main disadvantage of these spudders is that the force of the blow delivered by the tools cannot be regulated, inasmuch as the spudding arm is entirely disconnected from the power while the tools are falling. This is not such a serious disadvantage when drilling shallow holes through unconsolidated deposits, but it becomes serious when an attempt is made to drill deep holes through rock and other material hard to handle. This is due to the fact that in rock drilling it is often necessary to so regulate the stroke that the tools just touch the bottom, as when crevices are being passed, holes are being reamed and when work of similar nature is being done.

Another disadvantage of the uncontrolled spudder is that it cannot be run much more than 60 strokes per minute without battering the machine to pieces, owing to the fact that the spudding arm when released, flys back against a buffer with great violence, the force of the blow increasing as the hole deepens. Not only is this constant hammering of the spudding arm hard on the machine, but the infernal noise and racket which it produces is equally hard on the drill men and everybody else within a radius of a quarter of a mile of the machine.

The spudding device shown on page 23 is one that is particularly well adapted for handling rod tools as it embodies in a high degree all the features recommended on page 245, as necessary for a successful rod-tool spudder. The writer would therefore suggest that you study the principle of construction and operation of this spudder as it is representative of all that modern drilling practice has found to be the best along this line.

The other features, outside of the spudding device, previously mentioned as necessary for making a good rod machine, these being a positive means for controlling the feeding down of the string of tools and a sure and rapid method of hoisting and lowering the rods, will be discussed as we proceed with the descriptive matter.

As stated in the beginning of Part VIII, we will limit the term hollow rod tools to include only those used in hydraulic and jetting systems and in order to avoid confusion these two systems will be taken up separately.



Using Hollow Rods and working at a depth of 650 feet in a 2½ inch hole.

## Hydraulic System.

The main feature which distinguishes the hydraulic system from all other rod tool systems is the use of one or more valves placed along the line of rods, the purpose of the valves being to pump the cuttings from the hole and thus eliminate the necessity for bailing. When this system of drilling was first introduced it was the custom to place valves between all of the different sections of rods and much ingenuity was displayed in getting up valves which would fit into the couplings. At the present time, unless the hole to be drilled is of considerable depth, it is very seldom that more than one valve is used, this one valve being placed just at the top of the bit or at most not more than one joint above the bit.

It is remarkable with what force the water and cuttings are discharged from the drill rods when the tools are properly constructed and when they are working under conditions such as they are adapted for handling, but to obtain satisfactory results it is necessary that all parts be kept in proper proportion, as the principle of hydraulic drilling is based upon the action of a pump plunger in a cylinder, the drill rods and bit making up the plunger and the hole serving as a cylinder. These points will be gone into more thoroughly as the different tools and operations are described.

The principal parts making up an outfit of tools for hydraulic drill work naming them from the bottom of the hole upward, are:

Drill Bit,
Valve,
Drill Rods,
Change Rods,
Water Swivel,
Rope Hook,
Drill Rope.

The main accessories or other tools and appliances used with the above parts are:

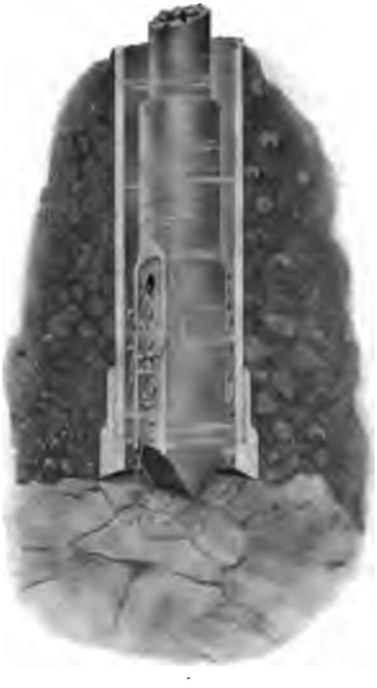
Drilling Weight,
Drilling Handle,
Sand Pump,
Sand Pump Line,
Pipe Driving and Pulling Tools,
Grab Hook,
Rod-Handling Tools,
Discharge and Return Hose,
Miscellaneous tools such as Chain Tongs, Pipe Wrenches, Pipe Vises, etc.

## Drill Bits.

Broadly speaking hydraulic drill bits are divided into two classes, these being designated as mud bits and rock bits. The mud bit, as a rule, is made somewhat thinner than the rock bit and is usually only about one-half the length.

A mud bit, as the name implies, is used for handling unconsolidated deposits. Originally it was used for all drill work above bed rock but modern drill practice has demonstrated that for hydraulic work the short bit is not an advantage, except under certain conditions. Thus at the present time the mud bit is generally used, when used at all, for starting the hole, and is replaced by the rock bit as soon as the first joint of pipe has been driven.

As a hydraulic bit must serve as both a drill bit and a pump, it is thus necessary to so proportion the various parts that the bit will fill both of the above requirements. If it were possible to make a bit which would fit the drill hole as snug as a plunger fits a pump cylinder, we would then have an arrangement which would show the very greatest pumping efficiency. Obviously this kind of a bit would not be practicable, even though it were possible to make it, owing to the fact that, while the pumping or self-cleaning feature would be efficient, the drilling rate would be cut to an extremely low point due to the retarding action of the closely fitting bit. Thus, in the designing of a bit, it is necessary to strike a compromise between the two requirements demanded and make the bit so that each of the essentials will be worked out to the point which will make the bit an harmonious whole.



Showing Action of Drill Bit on Bottom of Hole.

As different classes of formations work differently, some being easy to drill and hard to pump, and others hard to drill and easy to pump, it will thus be seen that it is impossible to make a bit with any one set of dimensions which will be just exactly best for all kinds of drilling, and thus there will be found a wide variety of different kinds, sizes and shapes of hydraulic bits on the market. In this respect however, the writer would caution you against "loading up" with a lot of different styles of bits as it is possible with one type of bit, if the same is correctly designed, to cover all ordinary classes of drill work, provided just a little change is made in the dressing of the cutting end when widely different kinds of formations are drilled.

The main points to consider in the making up of a hydraulic bit are, total length, width of blade, thickness of blade, depth and shape of water channel, size and position of discharge holes, thickness of bit just above the discharge holes and size of joint or coupling used.

As a rule the length of a new bit, including the coupling, should range from 20 to 26 or 28 inches, depending upon the size of the bit. When the hydraulic tools were first introduced it was supposed that the closer it was possible to get the discharge holes to the cutting edge, the more efficient would be the pumping action and thus the bits were made as short as possible. Even at this time this view is held by some drill manufacturers, also by a large number of drill operators. It has been the writer's experience, however, that when the blade of a bit is of proper width and thickness, much more satisfactory results can be obtained by the long bits. Not only will the long bits cost less to operate, due to the greater wear contained in them, but they will drill faster, will keep the hole straighter and will cause less trouble from clogged discharge holes.

The main disadvantage of short bits, outside of the matter of cost of operating, is that the discharge holes are liable to clog inasmuch as they are brought so close to the cutting edge that the material being drilled does not have time to thoroughly mix with the water and is thus so thick that it does not handle well. On the other hand, if the discharge holes are 18 to 20 inches above the bottom of the drill hole, the sludge has a chance to thin up a little before being drawn into the rods.

Of course, when rock drilling is being done, the matter of length of bit, in connection with heavy sludge, is not of so much importance as most rock formations cut clean, without making a heavy sludge. However, the long bit is to be preferred even for hard rock work as it keeps the hole truer, wears longer and is easier on the rods than a short bit.

While as already stated, there are many different sorts of hydraulic bits on the market, they being made up in all kinds of styles and shapes, still at this point we will confine our attention solely to what we will term the standard hydraulic bit and will leave the discussion of the merits of the special bits to a later chapter.

In making up a standard hydraulic bit, two types of bit blades are used, namely, the flat blade and the fluted blade.

The flat blade is used on bits for two-inch and two-and-one-half-inch work and the fluted blade on bits for holes of larger diameter. It seems to be the concensus of opinion that the flat blade is best adapted to the small work but is the writer's belief that a correctly designed fluted blade would be equally well adapted to small work. In fact for rock drilling from a theoretical standpoint, the small fluted blade should show a higher efficiency than the small flat blade.

The accompaning cuts show the two types of blades.

The fluted bit possesses two very important advantages over the flat bit, first, it will drill more rapidly and second, it will pump better. These advantages are, however, sort of compliments of each other as the extra drilling efficiency is largely the result of the effective manner in which the fluted bit cleans the hole.

The extra pumping efficiency of the fluted blade is due to the fact that by using the flutes it is possible to make the blades wider and thicker, thus forming a sort of plunger out of the bit. At the same time the force of the blow delivered on the bottom of the hole is not lessened, inasmuch as the sludge has a chance to pass upward through the flutes. It is this confining of the upward rush of the sludge to the channels formed by the flutes which gives the bit its great pumping power.

Bit with Flat Blade.

You will note by referring to the cut showing fluted bit that the discharge holes are drilled right at the top of the flutes and are thus so located that the sludge in its upward rush is forced into these holes. This action is further increased by making the shoulders above the flutes project quite a ways, thus forming funnel shaped pockets which have a tendency to scoop the sludge into the discharge holes.

You will note in the above that the writer speaks of the sludge as rushing upward. This is an action which takes place in the bottom of the hole, as the lifting of the tools causes the sludge to rush downward to fill the space occupied by the bit, and then as the tools drop, the sludge is displaced and rushes upward. It is this meeting of the falling tools and the upwardly rushing sludge which causes the best action on the part of the valve. It is also due to this downward and upward rush of sludge that the bottom of the hole is kept clean, as the movement of the sludge is such as to lift all of the cuttings off of the bottom and then rush them up through the flutes and into the discharge holes. Of course, in heavy clay and greasy shales the cleaning action is not so great, but when drilling in rock or drilling in sand, the reciprocating motion of the sludge, due to what might be termed the "suction" of the bit, is very important in making hole.

Bit with Fluted Blade.

From considering the above, you will now see the disadvantages of a thin bit, as the thin type of bit not only does not confine the sludge so as to force it against the discharge holes, but, being thin, it does not cause sufficient "suction" to make the sludge clean the bottom of the hole. Thus when drilling in rock with a thin-bladed bit, the heavy chips remain on the bottom of the hole until they are ground up sufficiently fine to allow them to be lifted. This necesssity for grinding up the heavy rock chips reduces the drilling speed quite materially, inasmuch as the full cutting effect of the edge of bit does not come upon fresh rock, but is partly cushioned by the cuttings present. On the other hand, the thick bit with its strong suction causes the bottom of the hole to be swept clean, thus giving the cutting edge a chance to do its most effective work.

As mentioned above, the shoulder should extend out quite a distance over the discharge holes and the flutes. As a rule, the diameter of the bit at this point should be from one-eighth to one-quarter of an inch less than the width of the bit blade, this diameter decreasing towards the pin or coupling.

By thus tapering off the collar it reduces the power required to lift the tools on the up stroke and yet does not affect the efficiency of the pumping action on the down stroke.

In drilling the discharge holes in a bit, the two "cut" holes, that is the two holes drilled in the sides, should be so run in that the angle made by a line drawn parallel with the bit blade and a line drawn parallel with the center of the hole, will be about 35 degrees. Some drill concerns make this angle as large as 60 degrees, but this makes a slow acting bit as the sludge has to enter the bit so nearly at right angle that its momentum is greatly reduced. Care should be exercised to see that the two holes are run in at the same angle so that they will meet in the exact center and will thus register with the hole drilled down from the top of the bit. The two side holes should be of slightly smaller diameter than the upper hole in order to prevent clogging of the bit.

The advantage of having the large hole at the top is that in case gravels or rock chips a little over size, or chunks of heavy sludge, are forced into the side holes, the bit will clear itself as soon as these obstructing particles reach the larger opening.

The size of coupling or joint used on a bit should vary with the size of the bit. While the proportioning of size of joint to size of hole is not of so great importance in rod drilling as in cable drilling, nevertheless it will be found that better drilling can be done and trouble can be avoided by keeping the different parts of a tool equipment in proportion.

Owing to the fact that many drillers have only one size of rods, which one size they use for handling all of the different sizes of holes, the manufacturers are often compelled to make up bits with joints entirely out of proportion to the work to be done. While there is one particular size of coupling which is best adapted to each size of hole, still the size can be varied somewhat without very noticeably impairing the efficiency of the bit.

In the bit table given further along it will be noted that with the exception of the two-inch bits, there is a variation in the size of couplings recommended. Thus in drilling a hole 2½ inches in diameter it is a safe proposition to use either a one-inch or a one-and-one-quarter-inch coupling; on three-inch work it is safe to use either a one-and-one-quarter-inch or a one-and-one-half-inch coupling, while in holes three-and-one-half inches in diameter, the size of couplings can be either one-and-one-quarter inches or one-and-one-half inches; also on four-inch work the couplings used can be either one-and-one-half inches or two inches. While it is possible to use larger couplings than those listed for all sizes of bits above two inches, still it is about as bad practice to use couplings of too large a size as to use them of too small a size. This is due to the fact that the drill rods used must correspond in size with the coupling on the bit, and, as increasing the size of the drill rod increases in a proportionate amount the area of the hole in the rods, the pumping efficiency is quite a little cut down, due to the fact that when the stream of sludge passes up through the bit it is allowed to spread and thus looses its force. These points will be gone into more thorougly when we take up the discussion of Drill Rods.

The coupling used on a bit differs slightly from the regular couplings used along the rods, inasmuch as the lower end of the coupling is faced off so that when it is screwed on to the bit, the dressed end of coupling will come snug against the bit shoulder, which should be faced off to receive it. This will take the strain off of the threads on the bit and will prevent them from breaking down.

In cutting threads on a bit they should be so cut that the coupling sets up hard, as this joint does not have to be unscrewed until the top part of coupling is worn out and by making it set up hard it lessens the danger of coming loose.

What has been said in the five preceeding paragraphs refers to those hollow rod tools using coupling joints. As will be more fully explained further along, rod tools are also constructed with box and pin joints and, as these joints are made up different from the coupling joints, bits having the box and pin joints will not have all of their dimensions the same as those equipped with the coupling joints. These points will be more fully brought out in the following table, which gives the dimensions of bits ranging in size from 2 to 4 inches.

Dimensions for bits of larger sizes are not given for the reason that the hydraulic system of drilling is not well adapted for holes larger than 4 inches, unless the material to be drilled is very easy to handle.

## Dimensions of Standard Hollow Rod Bits.

### Coupling Joints.

| Size of Bit | 2 | 2 1/2 | 3 | 3 1/2 | 4 |
|---|---|---|---|---|---|
| Width of Blade | 1 5/8 | 2 1/16 | 2 9/16 | 3 | 3 3/8 |
| Thickness of Blade | 1 | 1 5/16 | 1 15/16 | 2 1/4 | 2 1/2 |
| Total length of Bit, including Coupling | 21 | 21 | 26 | 26 | 26 |
| Weight of Bit | 10 | 17 | 25 | 30 | 40 |
| Size of Coupling to be used on Bit | 1 | 1-1 1/4 | 1 1/4-1 1/2 | 1 1/4-1 1/2 | 1 1/2-2 |
| Outside diameter of Coupling to be used on Bit | 1 11/16 | 2 1/16 | 2 5/16 | 2 5/16 | 2 13/16 |
| Diameter of side holes | 3/8 | 15/32 | 19/32 | 19/32 | 23/32 |
| Diameter of upper hole | 17/32 | 21/32 | 13/16 | 13/16 | 1 |
| Diameter of hole in valve plate | 3/8 | 1/2 | 9/16 | 9/16 | 3/4 |
| Diameter of valve ball | 1/2 | 5/8 | 3/4 | 3/4 | 1 |
| Internal Diameter of XX pipe of same size as Coupling | 3/4 | 7/8 | 1 5/64 | 1 5/64 | 1 1/2 |
| Internal Diameter of X pipe of same size as Coupling. | 61/64 | 1 17/64 | 1 31/64 | 1 31/64 | 1 29/32 |

### Box and Pin Joints.

| | | | | | |
|---|---|---|---|---|---|
| Diameter of Pin on Bit | Box and Pin Joints for this size cannot be made sufficiently heavy to do good work | 1 3/8 | 1 9/16 | 1 9/16 | 1 3/4 |
| Diameter of side holes | | 13/32 | 15/32 | 15/32 | 19/32 |
| Diameter of upper hole | | 9/16 | 21/32 | 21/32 | 13/16 |
| Diameter of hole in valve plate | | 3/8 | 1/2 | 1/2 | 9/16 |
| Diameter of valve ball | | 1/2 | 5/8 | 5/8 | 3/4 |
| Diameter of hole in box above pin | | 5/8 | 3/4 | 3/4 | 7/8 |

In explaining the above table we will first take up the bits fitted with coupling joints. You will note that for all bits with the exception of the two-inch bits, two sizes of couplings are given.

The meaning of this is that it is possible to use either of the two sizes listed. However, to obtain the very best results the larger size should be used, and, in making up the table, the writer has figured all dimensions as though the bits were to be fitted up with the larger sizes of couplings. While the size of coupling used does not influence such dimensions as "width of blade," "thickness of blade," "total length of bit" and "weight of bit," these dimensions remaining the same whatever the size of coupling, nevertheless, such dimensons as relate to the discharge holes and the valves depend directly upon the size of coupling. It will thus be seen that to vary the size of the coupling requires a like variation in the dimensions relating to the pumping part of the bit.

As has already been explained, all other things being equal, the bit that pumps the most satisfactory will drill the most rapidly, it is thus best that coupling used be of such size as to bring about the best pumping action.

In figuring on the sizes of discharge holes, several points have to be taken into consideration, the three main ones being, the size of coupling, the internal diameter of the pipe used immediately above the bit and the size of the valve ball.

The size of coupling to be used is determined by the size of the bit, it being the aim of the manufacturer to use a coupling of sufficient size to stand all necessary strains. However, care must be taken not to use too large a coupling as it will bind in the hole or else so fill up the hole that the tools do not drop well.

After having determined the largest size of coupling it is practicable to use on a bit of given size, the next point to consider is the internal diameter of the drill rod used immediately above the bit. Practical experience has demonstrated that the first two to six joints of rods should be made of double X pipe in order to stand up to the work and thus it is best to figure that the rod immediately above the bit will be of double X, or as it is usually written, XX pipe.

Having determined the size of coupling to use, also having determined that the XX pipe will be used immediately above the bit, the next move to make is to ascertain the internal diameter of the XX pipe, as this will then give us the dimensions of the space where the valve ball will work and will thus allow us to determine the size of ball.

After figuring out the largest ball it is possible to use, we are then in a position to figure out the size of hole in valve plate, also the diameter of the upper discharge hole and then from the above data, to figure out the diameter of the two cut holes.

From the above you will note that the working out of a successful hydraulic bit is not a hit-or-miss proposition, but is based on careful figuring and the design is so carried out as to make all parts in proportion.

Taking a 2½ inch bit as an example and referring to the table, you will note that a 1¼ inch coupling is the largest size that can be used as the external diameter of this size of coupling is 2 1/16 inches. Going on down in the table you will see that the internal diameter of 1¼ inch XX pipe is ⅞ inches. Careful experiments in all classes of drilling have shown that the valve ball should have at least ⅛ inch clearance on a side and figuring on this amount of clearance leaves a valve ball ⅝ inches in diameter. Now the valve ball should be at least ⅛ inch larger in diameter than the hole through the valve plate in order to allow for wear, and figuring on this basis the hole in valve plate should be ½ inch.

In figuring on the size of upper hole in the bit, it must be borne in mind that in order to get a quick action of the valve is is necessary to force the sludge against it with the greatest possible force and thus the upper hole in the bit should have a diameter slightly larger than the diameter of the hole in plate. Another point to be taken into consideration is that the diameter of the hole in plate gets larger, the longer the plate is used, and thus the upper discharge hole must be made of such diameter as to take care of this increase in size.

The diameters of discharge holes as given in the table have been settled on only after a long series of experiments, and while lack of space forbids that we discuss all the points considered in arriving at the sizes given, still the writer would suggest that you accept them as standard, at least until you are able to prove that other combinations of sizes give better results.

What has been said above refers to standard hydraulic bits which are to be used for general drill work where all classes of drilling will have to be handled. Where all of the drill work is through unconsolidated deposits such as clay, sand, gravel, etc., it is possible to use valves of larger sizes than those listed, if X pipe instead of XX pipe is used immediately above the bit.

The bit table shows the internal diameter of X pipe and by comparing the diameters of the X and XX pipe, and bearing in mind the method outlined above for figuring size of valve, size of discharge holes, etc., you will be able to figure out the proper dimensions for bits when the X pipe is used. One point you should bear in mind, however, when figuring on large valves, is that as the size of the valve ball increases, its hammering action becomes greater and thus it is best to hold the size of the ball down to rational proportions.

In the table giving the bit proportions when Box and Pin Joints are used, you will note that the discharge holes and valves are smaller than for bits of the same size where coupling joints are used. This is due to the fact that is impossible to make the hole through the box above the bit as large as the hole in the XX pipe above the bit when coupling joints are used and thus the valve ball and all other parts must be brought down in proportion. However, as hollow rod tools equipped with Box and Pin joints are primarily for rock work and as the sludge in rock drilling is, as a rule, not hard to handle, the decreasing of the size of the discharge holes and valve parts does not affect the efficiency of the bit.

If it is desired to use rods with box and pin joints for handling hard-pumping material such as clay and heavy sand, the pumping efficiency of a bit fitted with box and pin joints can be increased quite materially by using a valve cage on top of the bit. You will find this point more thoroughly discussed under "Hollow Rod Valves."

Another method by which the same results can be obtained is to use an extra long box above the bit and then bore out this box so that a larger ball can be used.

By adopting either of the above plans it is possible to use the same size of upper and cut holes on the box-and-pin bits as are used on the coupling bits.

## Hollow Rod Valves.

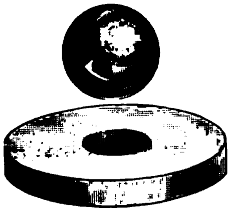
There are three general types of valves used in hydraulic drill work, these being the flat valve, the coupling or blind valve, and the ball valve.

The flat valve is made up somewhat similar to the flat valve shown on page 16, excepting that it is so arranged as to fit inside a coupling.

The coupling or blind valve is made up of a special type of coupling which is provided with a dividing shell about middle ways of its length. A hole is drilled through this shell which serves as the valve seat. The valve proper is made up a good deal in the shape of the dart valve shown on page 16, except that the dart extends above instead of below the seat and also the dart is made round, and tapers from the valve upward.

The third type of valve is known as the ball-and-plate type which consists of simply a plate and a round ball, as shown herewith.

The first two types of valves work very satisfactorily and are good valves, especially the blind valve, but as any valve used in hydraulic drill work wears rapidly, the expense of operating either the flat valve or the blind valve, owing to their much greater cost, is quite considerable, compared with the plate and ball valve.



Ball and Plate Valve.

As the plate-and-ball valve is every bit as effective as the other two types and as it is simpler and costs less, the writer recommends its use.

In operation, the valve is nearly always placed on top of the bit. Sometimes when drilling in quicksand which has a tendency to rush up into the rods and cover the lower part of the tools, the valve is placed up in the line of rods, generally in the coupling between the first and second joints. It is also customary at times to place several valves throughout the line of rods, but usually this is done only when very deep holes are drilled or when the sludge is so heavy that it has a tendency to settle quickly.

The placing of more than one valve in the rod line does not directly increase the pumping efficiency but it does add to it indirectly. The reason of this is that when a hole of considerable depth is being drilled, the total amount of cuttings contained in the rods is quite large and thus when only one valve is used and the tools are stopped the few minutes necessary for adding on another change rod, the cuttings are liable to settle back on the valve in such an amount as to make it impossible to start it into action.

By using several valves the amount of cuttings which will settle upon any one valve can be brought down to the point where the valves will start without trouble. This same advantage applies to the use of several valves when very heavy sludge has to be pumped. Another advantage to be derived from using several valves on deep-hole work, although this advantage is not so great as those already named, it is that in case the lower valve leaks, the pumping action will not stop.

As stated above, the plate-and-ball valve is a very simple mechanism, but to get the best results it is necessary that the parts be made in proper proportion and of the right material. The bit tables given on page 254 show the different sizes of balls to use, also the diameter of hole through plates.

As the hammering action of the ball on the plate is rather severe, it is necessary to make the plate of a good grade of steel and then temper it to an almost glass hardness The tempering will not only save the plate from excessive battering but will also prevent the sludge from cutting out the hole. When drilling in sharp sand rock, the cuttings are extremely abrasive and if a soft-steel valve plate is used, the hole is very soon cut out.

The best type of ball to use for general drill work is one made of steel, as it will wear well and will be of sufficient weight to seat itself properly. When the balls are of the larger sizes it is sometimes the custom to have them made up of some lighter material and the writer has on several occasions used an ordinary agate marble with good results. This answers the purpose very nicely for handling light sludge, but when the sludge is thick or heavy, the light ball is liable to be forced up into the rods.

The outside diameter of the valve plate should be of such size that it fits the coupling, or the box, if the box and pin joints are used, fairly snug, so that when the drill rod is screwed into the coupling, or joint, the plate will be held firmly against the top of the bit. Should the plate be loose, the sludge will work under and around it and cut grooves on the top of the bit and will also cut out the threads in the joint. If the threads on the drill rod have not been cut long enough to allow the rod to screw down firmly on the plate, the proper results can be obtained by using two plates instead of one.

A valve plate does not make a bit pump any better, and is used only to protect the top of the bit, which, without the plate, would soon be rendered useless due to the pounding action of the ball and the abrasive action of the sludge.

When connecting a bit onto a drill rod, the top of the bit should first be cleaned off perfectly clean. Next clean off the plate and place it on top of the bit. Now set the ball in the hole in plate and then screw the joint together. Some drillers do not place the ball on the plate at the time of connecting up the bit, waiting until after the rods are all connected up and then dropping it in from the top. As this method of placing the ball does not have any real advantages and as the dropping of the ball from the top may result in the ball ''hanging up'' in the rods, the writer would not consider it good practice.

The connecting up of a bit having box-and-pin joint, as a rule, offers a little more trouble than a bit with coupling joint. This is due to the fact that the valve plate and ball are not held in place by a coupling and thus may slip out of place a sufficient amount to make the plate bind in the box.

Also, the ball may roll from its seat on the plate and drop, either upon the ground or into the drill hole. Another trouble is caused by the rods becoming magnetized and lifting the ball from the seat. This latter trouble becomes so pronounced when drilling in certain formations that it is neces-to use a brass ball.

When the valve plate binds in screwing up the joint, the trouble can usually be remedied by lightly tapping the side of the rod with a hammer. This will jar the plate into place.

The ball can usually be prevented from rolling off the plate by using just a pinch of clay between the valve seat and the ball. The clay will hold the ball in place until the joint is screwed up and unless the chunk of clay used is too large, the ball will free itself upon the first stroke of the tools.

As already explained, a heavy sludge will tend to force the valve ball up into the rods. This can be prevented by placing a small pin through the drill rod, about 4 inches from the end which screws down on the valve plate. The easiest way to do this is to drill a hole through the drill rod, then cut off the pin to proper length and after placing it through the pipe, rivet both ends. The size of the pin to use depends upon the internal diameter of the drill rod, also upon the diameter of the valve ball. It should not be of greater size than is needed to so fill up the drill rod that the ball cannot pass. In order to prevent the rod from leaking where the holes have been drilled the ends of the pin should be riveted up close.

Some drillers use an appliance called a valve cage on top of the bit, between the bit and the first rod. This is usually made of soft steel and is so constructed that a slightly larger ball than those regularly furnished can be used. It is also, as a rule, provided with a pin or other appliance to prevent the ball from being forced upward into the rods. When box and pin joints are used, the valve cage will prove of some benefit if much drilling will have to be done through greasy clay or heavy sand. However, with the coupling joints the valve cage will show very little, if any, advantage, and is therefore not to be recommended where the coupling joints are used.

After a plate-and-ball valve has been used for some little time, its pumping efficiency increases quite considerably, due to the hammering action of the ball, which drives out the metal around the hole in the valve plate and makes a closer fitting seat. Thus, when drilling in sand and clay or in any material which does not pump readily, it is best to use a plate which has seen service.

When starting a hole it is the usual custom to drill down to a depth of 15 to 20 feet before placing the valve on the bit and starting the tools to pumping. In order to prevent the thick sludge from forcing itself up into the rods, from which it will be very troublesome to remove, a blank valve plate should be placed on top of the bit.

A blank plate is made up the same as a regular valve plate except that there is no hole through it. If you do not have a blank plate available, a piece of leather or thick gasket rubber cut to the right size will prove effective. If neither of these latter are available, then the upper hole should be plugged by driving a wooden pin into it.

## Drill Rods.

The service which can be obtained from a set of drill rods depends largely upon the material of which they are constructed. Thus your first consideration in selecting a set of rods is to see that they are made up of the right stuff. As a general rule wrought iron pipe will be found more satisfactory than steel pipe owing to the fact that most steel pipe becomes crystallized and is liable to break off just at the top of the coupling or joint. It must not be thought, however, that all pipe made of wrought iron will do for drill rods as it has been the writer's experience that some wrought iron seems to be "rotten," so that it breaks down easily. On the other hand, it cannot be said that it is impossible to make good rods out of steel pipe as there are certain grades of soft steel pipe which stand up almost as well as the best grades of wrought iron.

As a drill man does not handle enough different drill rods made up of different kinds and grades of material to enable him to judge from his own experience which is best, his safest plan is to leave the matter wholly in the hands of his drill manufacturer, as the manufacturer buys his rod material in large quantities and, in order to protect himself and customers, thoroughly tests out the material before placing his order for it.

When the hollow rod system of drilling was first introduced, ordinary merchant pipe was used for drill rods. Experience has demonstrated, however, that the walls of merchant pipe are not heavy enough to stand up to the work, so that it is now the almost universal practice to use pipe known as single X and double X, or as it is written, X and XX.

The following tables give the principal dimensions of X and XX pipe:

EXTRA STRONG.

| Size Inches. | Actual Outside Diameter, Inches. | Nominal Inside Diameter, Inches. | Thickness, Inches. | Nominal Weight Per Foot, Pounds |
|---|---|---|---|---|
| ½ | .840 | .542 | .149 | 1.09 |
| ¾ | 1.05 | .736 | .157 | 1.38 |
| 1 | 1.315 | .951 | .182 | 2.17 |
| 1¼ | 1.66 | 1 272 | .194 | 3.00 |
| 1½ | 1.900 | 1.494 | .203 | 3.63 |
| 2 | 2.375 | 1.933 | .221 | 5.02 |
| 2½ | 2.875 | 2.315 | .280 | 7.67 |

DOUBLE EXTRA STRONG

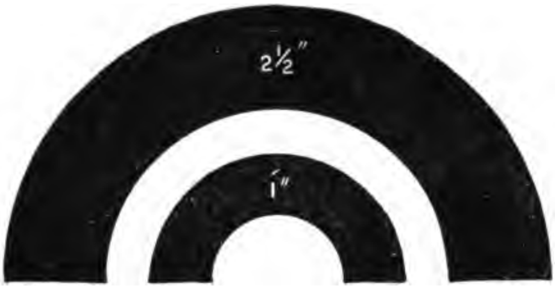
| Size Inches. | Actual Outside Diameter. Inches. | Nominal Inside Diameter. Inches. | Thickness, Inches. | Nominal Weight Per Foot, Pounds. |
|---|---|---|---|---|
| ½ | .84 | .244 | .298 | 1.70 |
| ¾ | 1 05 | .422 | .314 | 2.44 |
| 1 | 1.315 | .587 | .364 | 3.65 |
| 1¼ | 1.66 | .885 | .388 | 5.20 |
| 1½ | 1.90 | 1.088 | .406 | 6.40 |
| 2 | 2 375 | 1.491 | .442 | 9.02 |
| 2½ | 2.875 | 1.755 | .760 | 13.68 |

By comparing the wall thicknesses of the X pipe, given in the above table, with the wall thicknesses of merchant pipe given on page 34, you will note that the walls of X pipe are from 1⅓ to 1½ times greater in thicknesses than the walls of the merchant pipe. Also by comparing the wall thicknesses of the X and XX pipe, you will note that the walls of XX pipe are exactly two times greater in thickness than the X pipe. Another point you will note is that the outside diameter of a pipe of given size is the same for merchant pipe, X pipe and XX pipe. Taking a 1-inch pipe as an example, you will see that the outside diameter is 1.315 inches for all three sizes. By comparing the inside diameters, however, you will note that this dimension varies. Thus, in making the walls heavier, the metal has been added on the inside, decreasing the size of the hole in the pipe, but, leaving the outside diameter the same. By adopting the above form of construction it makes it possible to use the same size of coupling on the three different weights of pipe. The diagram on the following page shows the exact thickness of the walls of X and XX pipe, ranging from 1 inch to 2½ inches in diameter, and gives a very clear idea of the relative strength of a pipe of any given size when made in X and XX weights.

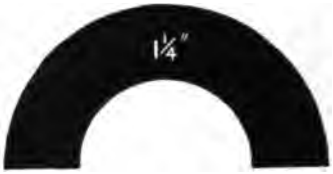
As stated on page 255 it is the usual custom to use two or more XX rods immediately above the drill bit, the reason for this being that the XX rods will stand up to harder work than the X rods and are thus better adapted to take care of the heavy strains which have to be borne by the bottom drill rods. Another advantage of the XX rods is that they are stiffer and will thus keep the hole straighter. By using the XX rods you also increase your drilling speed, as the more weight above the bit, the more hole that can be made.

This last statement regarding more weight, more hole, must however, be qualified somewhat, as there are limits beyond which it is not policy to go as the breaks which occur, due to extreme weight of rods, cause a greater loss of time than can be made up by the extra drilling speed.

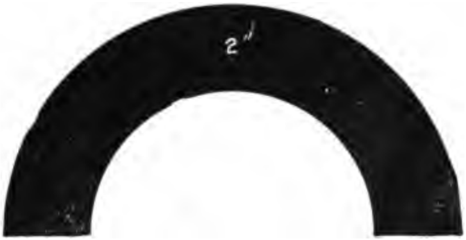
The proper size of rod to use in a hole of any given size is shown in the bit tables on page 254. However, as stated in the explanation covering the bit table, it is possible to vary somewhat from the sizes given. Thus when very deep holes are being drilled some drillers use 4 to 6, XX rods of proper size just above the bit, then several joints of X rods of the same size above the XX rods and then the rest of the rods are made up of a smaller size of X rods. Thus on a 2½ inch hole 800 feet deep, the rods would probably be made up as follows: 6-1¼ inch XX rods, 30-1¼ inch X rods and 14-1 inch X rods. The 6-1¼ inch XX rods and the 30-1¼ inch X rods would give ample weight for the best possible drilling speed and the 1 inch X rods would fill out. It is not absolutely necessary to fill out with the 1 inch rods, but as the use of the 1 inch X rods in place of



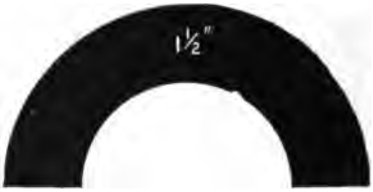
Double Extra Heavy.



Double Extra Heavy.

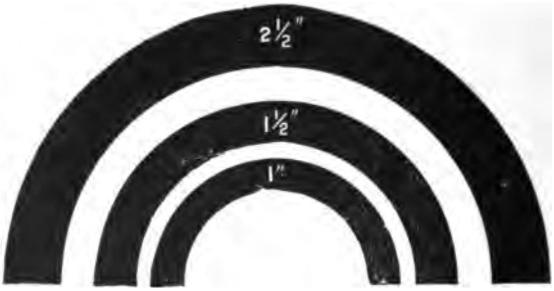


Double Extra Heavy.

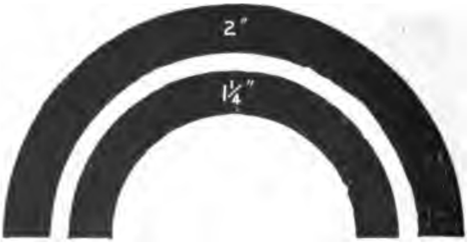


Double Extra Heavy.

The diagrams presented herewith show the exact outside and inside diameters of X and XX pipes ranging in size from 1 to 2½ inches, and give a clear idea of the wall thickness of the various sizes of pipe. While the table on page 260 gives the exact measurements figured to the hundredth and thousandth part of an inch and should thus be consulted when it is desired to make close calculations, still for roughly figuring out X and XX pipe sizes, measurements taken from these diagrams will prove sufficient.



Extra Heavy.



Extra Heavy.

the 1¼ inch X rods decreases the total weight something like 80 pounds, it takes quite a little strain off of the lower rod joints.

When the holes to be drilled do not exceed 500 or 600 feet, there is not much gained by decreasing the size of the rods as the saving in weight does not amount to much. Thus on 2½ inch holes 500 to 600 feet deep, the rods should be made up as follows, 4-1¼ inch XX rods and 34-1¼ inch X rods.

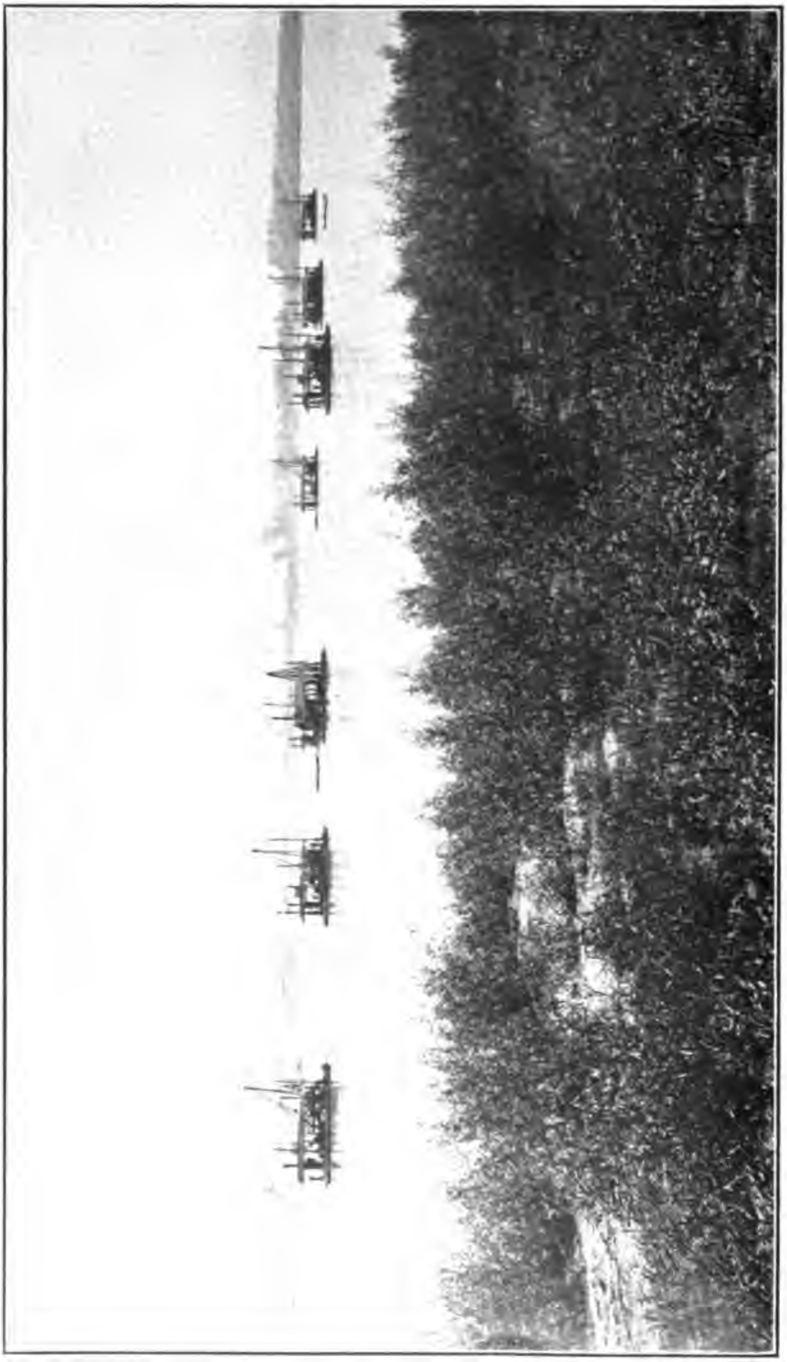
Some drill manufacturers in making hollow rods use, besides the X and XX pipe, a pipe which they call hydraulic pipe. This is nothing more than full weight pipe and is but slightly heavier than ordinary merchant pipe. The hydraulic pipe will prove very satisfactory for filling out at the top of the hole but owing to the comparative thinness of its walls, it is not to be recommended for heavy work.

In order to stiffen up the rods just above the bit and also to get the weight down on the bit where it is the most effective, some drill manufacturers furnish one or more drill rods of a larger size than those ordinarily used, swaging down the ends of the big rods until couplings of a size which will go into the hole can be used. Thus, for two inch holes it is a good plan to use two or four 1¼ inch XX rods just above the bit and then finish out the string of rods with 1 inch X rods. The four 1¼ inch XX rods give good weight for drilling and stiffen up the rods in the bottom of the hole so as to keep the hole straight.

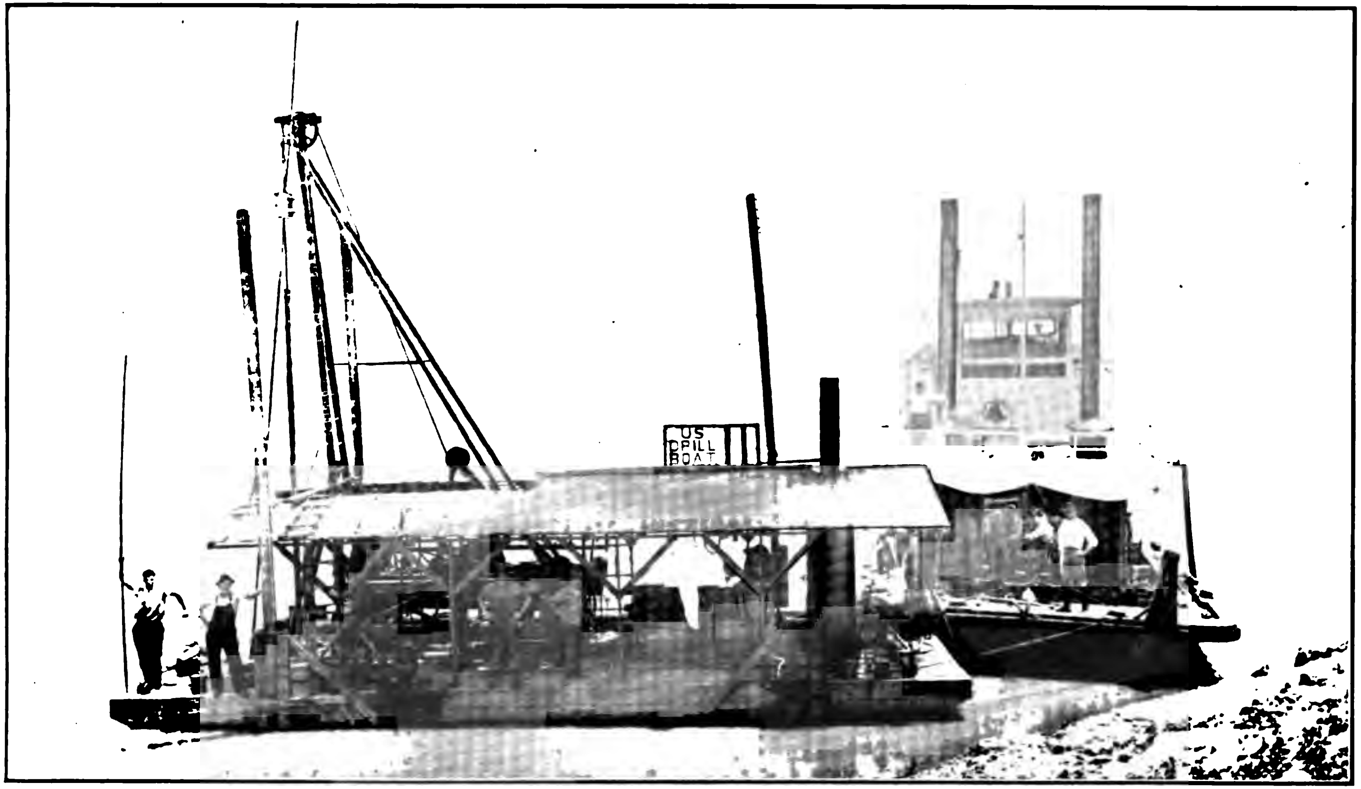
By referring to the hydraulic-coupling table on page 38, it will be seen that a 1¼ inch coupling has an outside diameter of 2.07 inches and thus is too large to go into a 2 inch hole. As the outside diameter of a 1¼ inch rod is only a little more than three-tenths of an inch greater than a 1 inch rod, all that is required is to swage down the ends the desired amount and then cut threads for a 1 inch coupling.

Not only is it a good plan to swage down 1¼ inch rods for the bottom rods on 2 inch holes, but it is also a good plan to swage down heavier rods for holes of larger diameter. Thus on 3 and 3½ inch holes it is often a good plan to swage down a 2 inch XX pipe so that it can be fitted with a 1½ inch coupling.

When box and pin joints are used and holes 3 or 3½ inches in diameter are to be drilled, it is best to always use a 2 inch XX rod swaged down to proper size. By using a 2 inch XX rod swaged on the lower end to a 1½ inch box and swaged on the upper end to a 1¼ inch pin, holes 3 to 3½ inches or even 4 inches in diameter can be drilled with the small 1¼ inch box and pin joint rods. Thus the driller equipped with a 1¼ inch box and pin outfit for drilling holes 2½ inches in diameter can arrange his outfit for handling holes 3 to 4 inches in diameter by getting a 2 inch XX rod swaged as above, and bits of the sizes needed.



Ten specially designed Cyclone Hollow Rod outfits used by the United States Government in sub-aqueous testing in the Ohio river.



Method of mounting the above drilling outfits on board the scows.

In swaging the end of a rod, care must be exercised to see that the metal is brought down evenly on all sides so that the walls of the rods, after the swaging is done, are of equal cross section and strength. Should the metal not be evenly distributed the rod is liable to break down on the weak side, thus telescoping the rods. Another point to watch is to see that the walls are not made too thin for should this occur the rod will be weak when the threads are cut or the joint welded on.

The proper length to make drill rods is a question that cannot be definitely settled owing to the fact that manufacturers have different ideas along this line. Some manufacturers say that the rods should be at least 20 feet long as the longer the rods the less the number of joints in the hole.

While it is good policy to keep the number of joints down to as low a point as practicable, still it is not best to go to extremes in the length of drill rods in order to obtain this result, as increasing the length of rods above a certain point, increases the chances for trouble.

Rods of extreme length are not only hard to handle around the machine, but they are also hard to handle when moving from place to place, as it is nearly always impossible to get a wagon of sufficient length to carry the rods without the ends projecting dangerously beyond the end. Rods of extreme length are also liable to open up along the weld.

The writer's experience is that a rod 16 feet in length is the one most easily handled and the one which will give the best all around service. By having sixteen-foot rods it is possible to pull two joints at a time and stand them in a derrick 22 to 25 feet high. It is also possible to use change rods only 4 feet long and thus the handling of the swivel and discharge hose becomes a simple matter.

In handling rods about the machine or when moving, care must be taken to see that they are not bent nor twisted, and if they are not to be used for some time the joints should be carefully oiled, and the rods laid on sills spaced 4 or 5 feet apart and so arranged that the rods are kept level.

In unloading, do not throw the rods on to the ground as this is liable not only to bend them, but also to cause them to open up along the seam.

Never use a bent rod in the hole, as even a slight bend will cause the rods to rub against the walls of the hole and will thus cause excessive wear. Another objection to a bent rod is that it has a tendency to give a springy blow to the tools and it also tends to place an uneven strain upon the joints.

When a rod is but slightly bent, it can be straightened by placing it over a block and then bending it back into shape. For work of this kind the rod can be handled cold, but when there is a considerable crook to be taken out, the rod should be heated, in order to prevent the seam from opening up. In heating, do not get the rod hotter than a light cherry red and while the rod is in the fire, keep turning it so that all sides are heated to the same temperature. If you find it necessary to do any hammering on the pipe you should use a round swage as driving down on the pipe with a hammer is liable to crush in the wall.

When doing drill work in the winter time care must be exercised to see that the water has drained from all of the rods which will remain in a freezing temperature, for should the water in the rods freeze, it is more than likely that the rods will be opened up at the seams.

## Change Rods.

Change rods are used simply as a matter of convenience. If only full length drill rods were used, it would be necessary to work the water swivel at a height of 16 to 18 feet above the ground each time a new rod was added on, and as this would in turn require the use of a discharge hose 25 to 26 feet long, it would make the handling of the rods a troublesome proposition. As the rods can be most easily controlled when the water swivel is kept within 6 or 8 feet of the surface of the ground, it is the usual custom to use change rods of such length as to keep the swivel within these limits.

When the length of the drill rods is 16 feet, the length of the change rods should be 4 feet, as this will allow the using of 3 change rods and will make it unnecessary for the lower end of the swivel to come more than 4 to 5 feet from the surface of the ground at any time during rod changing operations. Thus, in drilling operations, the first change rod is added on and the hole drilled down the length of the rod, then the second change rod is added on and the hole drilled down, then the third rod is added on and the hole drilled down as far as the third rod will reach. You now have all three change rods in the hole and you have drilled down 12 feet. You are now in a position to put a full length drill rod in the hole without having to elevate the swivel to a troublesome heighth. This can be done as follows: Hoist the drill rods from the hole until the three change rods come above the surface. Remove the three change rods, and in their place screw on a regular 16 foot rod. Next lower the rods back into the hole and when the bit is on the bottom, the top of the rods will come just about 4 feet above the surface. By following the above method of handling the rods it is possible to always keep the water swivel within easy working distance of the ground.

As a rule change rods are made of X pipe, the manufacturers claiming that inasmuch as the change rods are used at the top of the hole they are not subjected to heavy strain and thus do not have to be made up of any heavier material.

While it is true that the change rods do not have much weight above them, still, owing to the fact that the change rods are used more often than any other rods, and also owing to the fact that they are often subjected to pretty rough treatment in being thrown around, the writer recommends the use of rods made of XX pipe.

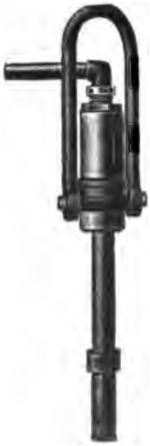
Another point to be taken into consideration is that the change rods have to stand up to rather heavy side strains due to the rods being used a large part of the time outside of the hole. These strains are caused by the whipping back and forth of the swivel which may at times become very violent if the tools are not being intelligently operated.

## Hydraulic Water Swivel.

In order to make it possible to connect onto the drill rods with the drill rope, also in order to take care of the sludge which discharges from the rods, it is necessary to place at the top of the rods, some sort of an appliance, through which the rope hook can be fastened, and to which a hose can be attached. When the hydraulic system of drilling was first introduced this appliance consisted simply of a tee which was screwed onto the top rod. Into the upper part of the tee was screwed a piece of pipe which was bent around and welded so as to form an eye for the rope hook, while into the side of the tee was screwed a short nipple over which the discharge hose was fastened.

The tee arrangement, while very simple, was troublesome to operate owing to the fact that as the tools were turned the rope would be twisted and also the hose would be wrapped around the drill rods.

In order to get around the above troublesome features a swiveled arrangement was finally evolved, whereby the rods were allowed to turn without causing the rope to twist or the hose to wrap up. Swivels have been constantly improved until at the present time the swivels turned out by some of the manufacturers are about all that could be desired.



Ball Bearing Water Swivel.

The main requisites of a swivel are as follows:

It should be of sturdy construction so as to be able to stand up to hard work without causing trouble.

It should be so constructed that the rods can turn freely, without twisting the rope or the discharge hose.

It should be so arranged as to be easily handled.

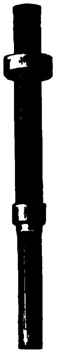
It should be made so that it does not leak.

The water swivel shown in the accompanying cut embraces in a high degree all the requisites named above.

Considering the swivel in detail, it is made up of the following parts: Main Stem, Swivel Plate, Swivel Plate Bail, Ball Bearings, Packing Box, Packing Nut, Lock Nut, and Discharge Stem.

The main stem is made up of the very best grade of XX pipe and has welded onto it two collars as shown in the cut on next page. The lower collar is for holding the drill handle or the drilling weight in place. In turning up this lower collar the upper side of collar should be cut straight while the lower side should be sloped off down to the stem. By cutting the upper side straight it will make a square shoulder for the handles or weight to rest against and will thus prevent them from being driven down. By tapering off the under side of the collar it will prevent the collar from "hanging up" on the drive pipe should it ever be necessary for the stem to go into the hole.

The upper collar on the stem forms a seat for the swivel plate and its upper surface should be faced off square with the stem in order to make the swivel hang without binding.

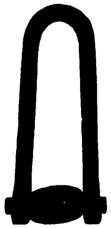

**Main Stem.**

The upper end of the stem is threaded, the threads being cut for a distance of about 1½ inches back on the end. The threads are cut on a taper, the taper being so figured that when the stem is screwed solidly into the packing box the upper collar on stem comes up just far enough to hold the ball bearings firmly in place. Should the swivel plate or the ball bearings wear thinner, the slack can be taken up by screwing the stem into the packing box a little further. The threads on the stem are right handed and thus the stem should be turned to the right in case it is desired to take up the slack.

The swivel plate should be of the best grade of steel and should be faced off on both sides so as to make an accurate fit with the stem collar below, and the ball races above.

The swivel-plate bail should be made up of two kinds of material, steel in the upper part of bail where the wear of the rope hook comes and Norway iron at the lower ends where the eyes are formed

The ball bearings used on a swivel have to stand up to hard work and thus the ball races must be made of the very best grade of steel and must be of ample size to stand the strains. The balls must also be of the very best material and construction as the replacing of a broken ball is a rather troublesome proposition.


**Swivel Plate and Bail.**

To put in new bearings or a new swivel plate it is necessary to unscrew the stem from the packing box. If the swivel has been in use for some time the threads may so bind that it is impossible to start the stem. Should this trouble arise, it can usually be overcome by heating the packing box. To do this, first remove the discharge stem, the lock nut and the packing nut. Next lay the packing box on top of a bed of live coals and keep turning it so as to heat it evenly. Never heat it over a dull red, and if it is possible to do so the stem should be unscrewed before the packing box reaches this heat. By allowing a small amount of water to flow through the stem, just before trying to unscrew it from the heated box, may assist matters.

**Ball Bearing for Swivel.**

There are now on the market a great many hydraulic swivels which are not provided with ball bearings and while these swivels are probably a little more "fool proof" than the ball bearing swivels, still, owing to the roughness with which they work, they are not to be recommended.

The packing box for swivels should be made of soft steel and, for swivels of ordinary size it is usually about 5 inches long by 3 inches in diameter. The hole through the box is bored about 1½ inches in diameter and as the external diameter of the discharge stem for swivels of ordinary size is 1⅛ inches, this allows a space of 3/16 of an inch around the stem which can be used for packing.

Packing Box.

The bottom part of the box is tapped out for a distance of about 1½ inches, the threads cut being ordinary eleven-and-one-half-to-the-inch pipe threads and cut on a taper, as explained above.

The upper part of box is tapped out for a distance of about 2 inches, the threads cut being left-handed and cut eight to the inch. These upper threads are made heavy in order to make the packing nut set up easily, and are cut left-handed in order to prevent the packing nut from unscrewing, as the rods are turned to the right. As a further precaution, to prevent the packing nut from backing off, a lock nut is screwed onto the packing nut and is set up against the box as soon as the packing nut has been set down on the packing.

The discharge stem should be made of cold-drawn, seamless steel tubing with an outside diameter of 1⅛ inches and an inside diameter of ¾ of an inch. The reason for using the above material is that it not only makes and extremely strong stem but, inasmuch as the outside surface of cold-drawn tubing is very smooth it does not cut out the packing. The size of tubing named above is recommended for the reason that it fits into a one-inch hose very snugly.

Discharge Stem.

Owing to the fact that a discharge stem is subjected to considerable hammering it should be made of one piece of tubing, bent into the shape desired. The accompanying cut of a discharge stem would indicate that it is made up of two separate parts screwed into an elbow but this seeming elbow is simply a casting cast onto the stem after it has been bent. This casting not only makes the stem stronger at the bend, but it has the added advantage of preventing the stem from becoming jammed into the packing nut.

While the cut of discharge stem shows a stem bent at right angles and while most stems are made in this form, still it has been the writer's experience that the outer end of the stem, to which the hose is attached, should bend down somewhat in the form of a "goose neck." The reason for so shaping the stem is that the shearing strain on the hose will be greatly decreased and thus the hose will last much longer.

In packing a swivel it is necessary to fill the packing box as full as possible so that when the packing nut is screwed down the packing will be sufficiently compressed to prevent the sludge from leaking up into the box. It is very important that the swivel be properly packed at the start, for should the gritty sludge force itself up into box it will become mixed with the packing so that the packing will soon be ground out. Another trouble is that the discharge stem will be worn rough so that even when newly packed it will be a hard matter to keep it tight. In case you do not get the swivel properly packed and it starts to leak, the best plan is to remove all the packing, clean out the box and re-pack with clean packing.

As the packing is placed in the box it should be liberally oiled as the oil will prevent wear.

To do the packing properly, you should be provided with a packing "hook" of such shape and length that you can force the packing firmly down around the discharge stem. As the lower end of the discharge stem extends about 4½ inches down into the top of the main stem, it is thus possible to lift the discharge stem 3 or 4 inches when packing and this will give you ample room to handle the packing "hook."

As just stated, the lower end of the discharge stem passes down into the top of the main stem, which is reamed out the right amount to make a close fit.

The kind of packing to use in packing a swivel is a much disputed point among drillers, some preferring one kind and some another, but it has been the writer's experience that for a low-priced, comparatively long-lived packing, Italian hemp is hard to beat. If first cost does not scare you and you want a packing which will give you the very longest possible service, use Palmetto square braided hemp, laid up in tallow and graphite.

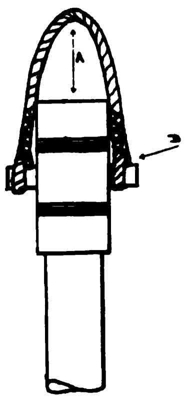
Packing Nut.

In order to keep the swivel from leaking, the packing nut should be set down a little from time to time. By keeping the packing tight you not only preclude leaks but you also prevent the discharge stem from hammering up and down, an action which not only grinds out the packing, but also wears out the discharge stem.

When drilling, the slack in the drill rope should be so let out and the stroke so adjusted that the rope hook does not hammer the bail of the swivel as the hammering action is extremely hard on both the ball bearings and the eyes of the plate bail. When drilling in hard rock, some drillers use a short piece of rope between the rope hook and the bail, and as this prevents all hammering between the hook and the bail, it protects the swivel quite materially.

Lock Nut.

The best way to arrange a rope for the above purpose is to splice an eye on each end of the rope, after which pass the rope through the bail and then place the two eyes over the rope hook. As it takes but a second to slip the two eyes on or off of the hook, the use of a piece of rope does not interfere in any way with the rapid handling of the tools. For ordinary drill work a piece of ⅞ inch, soft-laid rope is of ample size. The length of rope after the eyes are spliced in should be about 16 inches.



Quick Repair Rope Bail.

A piece of rope can also be used for making a quick repair when the bail or the eyes of bail become broken. The accompanying cut shows the way this is done. The eyes which are spliced in the rope should be of such size that they fit the lugs on the plate very snug. The length of rope after the eyes are spliced in should be such that the distance marked "A" is 6 to 8 inches. The writer used the above appliance one time when drilling in an unsettled country where supplies were slow in coming, and in order to test out its wearing qualities left it on the swivel for about four weeks, at the end of which time it was still in fair condition.

To protect the ball bearings on a swivel from the wearing action of the grit and sharp cuttings, the ball races should be kept pretty well filled with hard oil or cup grease. If you have no hard oil, good heavy axle grease will do, or if there is no axle grease on the job, soap can be used.

When the wear on the upper shoulder on the stem, the swivel plate, the ball bearings or the lower part of packing box, becomes so great as to allow too much play, the swivel should be tightened up by screwing the main stem further into the packing box. If the threads on the stem are not long enough to take up all the slack, the stem should be unscrewed from the box and the threads cut back further. Care must be exercised in doing this however, as the threads must be so cut that the stem, when screwed solidly into the box, will bind the ball bearings just enough to hold them.

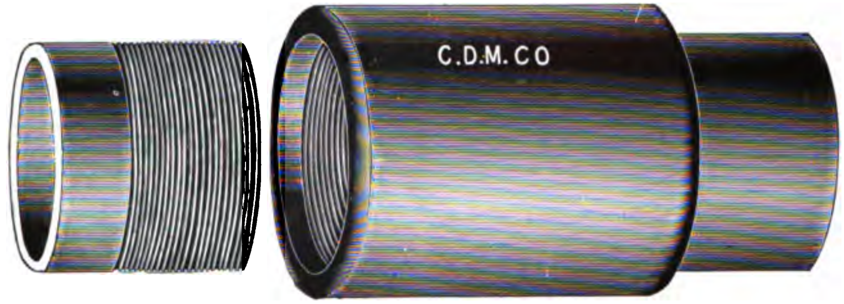
## Hollow Rod Joints.

Two types of joints are used on hollow rod tools, these being known as coupling joints and box-and-pin joints.

The coupling joint is much the older of the two and is thus more generally used.

When nearly all of the drilling will be through unconsolidated deposits and not much hard rock will have to be penetrated, the coupling joints are to be preferred on account both of their better drilling efficiency and their lower first cost. Another advantage of the coupling joint is that it can be easily repaired by the man in the field without the use of special tools.

The better drilling efficiency of the coupling joint when used in unconsolidated deposits is due to the fact that the internal diameter of the rods is not reduced at the joints and thus the upward rush of the sludge is not checked by constricted passages. Another advantage obtained by having a clear passage through the rods is that in case the rods become choked with sand or sludge they can be easily cleaned.



Hydraulic Coupling Joint.

The disadvantages of the coupling joint when compared with the box-and-pin joint are first, they do not drill consolidated deposits as rapidly, second, they are more liable to telescope when subjected to hard work, and third, they require a little more time in screwing together and unscrewing.

In cutting threads on a drill rod, they should be cut on a slight taper, the taper being so figured and the threads cut to such a length that the end of the drill rod comes within a short distance of the center of the coupling. By cutting threads in this manner, it makes the rod bind firmly in the coupling, thus preventing the joint from getting loose. Some drillers cut the threads so that the rods meet in the coupling, claiming that when the rods butt, the strain on the threads is lessened. While this is true to some extent, still it has been the writer's experience that when the rods meet in the coupling, the ends of the rods become burred thus making them hard to unscrew. Especially is this so when the rods are used on hard rock work. A better way to protect the rods is to place one or more washers in the coupling, against which, the ends of the rods can be screwed. By doing this it is possible to cut the threads on a taper and then as the threads wear smaller or the couplings get larger one of the washers can be removed to allow for the variation. If washers are used it is a good plan to slightly bevel the ends of the rods so that should a burr form, it will not bind in the coupling.

The washers used for the above purpose should have a hole through them about the same size as the hole through the rods so as not to obstruct the flow of the sludge.

The length of the thread to cut on a rod depends upon the diameter of the rod, as the larger the rod the longer the coupling.

The following table gives the proper length of thread for rods up to 2 inches in diameter. The table also gives the lengths of XXX couplings, thus making it possible to figure the distance between the ends of the rods when the joints are fully set.

**Thread and Coupling Table.**

| | | | | |
|---|---|---|---|---|
| Size of Drill Rod | 1 | 1¼ | 1½ | 2 |
| Length of XXX Hydraulic Couplings | 2½ | 2¾ | 2⅞ | 3½ |
| Length of Thread Cut on Rods | 1⅛ | 1¼ | 1⅜ | 1⅝ |

Should the threads on the rods get in bad shape, the end of the rod should be cut off and new threads cut. If the rods are to be used in couplings which has been in service a good while, it may be necessary to hold up the threads somewhat larger than if the threads were being cut for a new coupling, owing to the fact that old couplings are generally a little over-size. In order to be able to vary the threads cut, an adjustable die should be used. The Armstrong Dies shown herewith, or dies built on the same order, are the best for handling rod work.

Armstrong's Pipe Dies

Barnes Pipe Cutter.

The other tools needed for cutting threads, are pipe cutter and a pipe vise. These tools are shown herewith.

As a general rule the vise is mounted somewhere on the machine so that it will always be in place.

In cutting threads, try to cut them without stripping any of them as a broken thread allows grit to get in around it and this will cause the threads to bind in the coupling and is very liable to result in the threads raveling. The use of plenty of oil and the exercising of extra care in backing the dies off of the threads will greatly assist in making a good job.

The couplings used for connecting the drill rods are known as Three X Hydraulic, or as it is usually written, XXX Hydraulic. These couplings are very much heavier than ordinary couplings and are also quite a bit longer. With the exception of some special types of couplings which are punched from forged steel, all couplings for rod work should be made of wrought iron. The advantage of the wrought iron coupling is that the threads are tough and will not crystallize and thus the coupling will not only last longer but it will also preserve the threads on the rods.

Hinged Pipe Vise.

Rod couplings are now made with either straight ends or recessed ends. Theoretically, the recessed coupling should be the more satisfactory inasmuch as the sleeve, extending up along the rod, should protect the threads from the side strains. However, in actual practice the recessed coupling develops faults, which in some ways, make it unsatisfactory for drill work. These faults are as follows:

First. The rod sometimes binds in the sleeve, thus preventing the threads from being firmly set up.

Second. The coupling being thin at the outer ends of the sleeve, it makes it easy for a break to start. Especially is this so if the weld has not been properly made.

Third. The sleeve affords an opening where grit and sludge can settle and this will bind when the joint is unscrewed.

When new rods are used for the first time, all of the threads on the rods and in the couplings should be carefully cleaned to remove any chips which may remain from the thread cutting operations, as these chips if allowed to remain will be apt to destroy one or more threads when the joints are set up. An old tooth brush makes a handy tool for this cleaning work. For cleaning the threads on the rods, a thread chaser made as shown on page 41, is also a handy tool.

During drilling operations the threads must be cleaned each time the joints are screwed together as the presence of sludge on the threads will not only tend to cut them out but is also apt to cause them to strip when the joint is uncrewed. If the threads are very rusty, or if there are several broken threads in the coupling, or on the rod, the joints should be oiled before being set up. If the threads are in pretty good shape it is better to use water with a little soap in it as the joints will not be so apt to unscrew during drilling operations.

As the couplings on rods wear quite rapidly, especially when sand rock is being drilled, they must be carefully inspected each time the rods are pulled from the hole. Especial care must be exercised in examining the joints on rods used in a deep hole as joints which are of ample strength for shallow drilling may prove unable to stand up to heavy strains of deep work. If a coupling looks weak, it should be replaced by a new one, or if the threads on a rod look defective, a rod with new threads should be substituted. The old rod should be laid aside until after drilling operations are again started, when the helper should re-thread it.

When it is desired to connect a drill rod of a certain size onto a drill rod of larger or smaller size, a special coupling known as a reducer is used. The best type of reducer is made of forged steel and the opening through it is either punched or drilled. By making the coupling in this manner it avoids the presence of a weld.

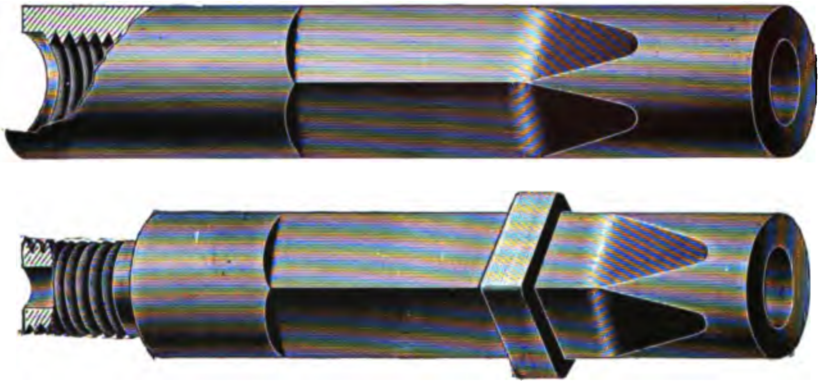
Another method of reducing from one size of rod to another is by the use of a bushing. The bushing is made to screw into the coupling on the larger rod and then the smaller rod is screwed into the bushing. This bushing should be made of forged steel and the hole drilled or punched through it the same as the reducer described above.

## Box and Pin Joints.

The manufacture of the box-and-pin joint was brought about by the demands of the driller for a joint which would stand up to hard rock work. As already explained, when using coupling joints the force of the drilling blow is carried by the threads and thus in hard rock the joints are liable to telescope, due to the stripping of the threads or the expanding of the couplings.

In getting up the box-and-pin joint it was the aim of the manufacturers to construct a joint along the lines of cable-tool joints, that is, to make a joint in which the force of the drilling blow would fall upon flat shoulders and not upon the threads.

The accompanying cuts make clear the construction of the joint which was finally evolved and show how, when the joint is set up, the drilling blow is carried by the shoulder instead of the threads. You will note, however, that the pin differs from a cable-joint pin inasmuch as it is cut straight instead of on a taper it being necessary to use the straight pin on account of the hole drilled through it.



Box and Pin Joints.

Both the box and pin are made up of solid pieces of soft steel which are roughly shaped and then welded into the rods. After welding, the joints are turned, and bored, after which the threads are cut.

In welding, in order to make the weld stand up to hard work, the end of the soft steel is worked down so that it can be driven up into the rod for a distance of about 1½ inches. Thus, should you ever desire to cut off a joint, you should measure back on the rod for a distance of about 2 inches from the point where the pipe is welded, or otherwise it will be neceessary to cut through both the pipe and the soft steel used in the joint.

Box-and-Pin-Joint Wrench.

Owing to the fact that box-and-pin joints rely upon the friction between the shoulders for holding them together, it is necessary to set up the joints much closer than coupling joints. In order to be able to do this the joints are provided with wrench squares and special tool wrenches are used. In setting up the joints, they are first screwed together by hand until the shoulders meet and then the wrenches are put on. In handling the wrenches, they are to be used as right hand and left hand the same as cable tool wrenches, the left-hand wrench being placed on the square on the lower part of joint and the right-hand wrench being placed on the square on the upper part of joint. In tightening the joint the wrenches are "snapped," not pulled, together.

To "snap up" a joint, catch the lower wrench in the left hand and the upper wrench in the right hand and then jerk the ends of the wrenches violently towards each other. As the opening in the wrenches is a little larger than the square, it will give quite a little play to the wrenches, and the jerking of the wrench handles will drive up the joint very firmly. There is quite a sleight about "snapping" a joint, and you may not be able to set them up very tight at the start, but after you once get the "hang" of it, you will be able to put them up so they will stand firm.

What has just been said refers to tightening a joint. The loosening involves the same procedure except that the position of the wrenches is reversed; the left-hand wrench going on the square above and the right-hand wrench on the square below.

Before setting up the joints on new rods, the threads on the pin and in the box should be carefully cleaned. It is also a good plan to stand the rods on end and tap them lightly on the side with a hammer so that any chips, from the boring of the hole or the cutting of threads, which are in the pipe, will be removed.

In cleaning the threads, remove all grease and foreign matter and if the shoulders have been bruised or roughened they should be smoothed up. When box-and-pin joints are new the threads are liable to have a wire edge on them and thus the first three or four times they are set up they should be pretty well oiled in order to prevent this wire edge from curling up and stripping the threads. In oiling the joints, however, try to keep the oil off of the shoulders as a film of oil between the shoulders will tend to make the joint come loose.

After the threads have smoothed up somewhat from wear, the oil should be entirely removed from them and nothing but clear water used in in cleaning them. The instructions given on pages 12 and 13 covering the care of joints on cable tools applies, with the exception of oiling noted above, to the care of joints on rod tools.

In taking care of the box-and-pin joints on change rods, it is the usual custom to depart somewhat from the instructions given above, inasmuch as these joints are kept fairly well oiled. The reason for this is that these joints are used so often that, unless lubricated, they will wear rapidly. As the change rods are always used at the top of the hole and as they thus do not have much weight above them it is better to take the slight chance of the joints coming loose, in order to prevent wear. However all rod joints which go into the hole should have the oil removed and thus when taking off the three change rods to put on a full-length rod, the pin from which the bottom change rod was unscrewed should be cafefully cleaned before putting on the new rod.

As stated on page 255, the first one to six rods on the bottom should be made up of XX pipe and inasmuch as a valve plate is used on top of the bit pin it is necessary to have the box of the rod which screws into the bit somewhat deeper than an ordinary box. Thus the boxes on all XX rods should be cut deep enough to accomodate the pin with the plate on top. In cutting these boxes, however, care must be taken not to get them too deep as the box must be of such depth that when the joint is set up the plate will be held firmly against the pin. If the plate has a small amount of play in the box, the sludge will work under and around it and will cut out the top of the pin so that the sludge will leak past the valve plate.

As change rods are sometimes used in starting a hole, when the rock outcrops, or is within 6 or 8 feet of the surface, it is necessary to have the boxes of the change rods bored out the same as the boxes on the full-length XX rods, so that a blank valve can be used on top of the bit pin.

The followimg table gives the main dimensions of box-and-pin joints:

**Dimensions of Box and Pin Joints.**

| Size of Pipe, inches | 1¼ | 1½ | 2 |
|---|---|---|---|
| Smallest Hole to be used in, inches | 2½ | 3 | 3½ |
| Diameter of Pin, inches | 1⅜ | 1 9-16 | 2 |
| Length of Pin, inches | 1⅜ | 1½ | 2 |
| Diameter of Pin Collar, inches | 2⅛ | 2⅜ | 3 |
| Diameter of Box Collar, inches | 2⅛ | 2⅜ | 3 |
| Length of Pin Collar, inches | 2¾ | 3 | 4 |
| Length of Box Collar, inches | 3½ | 4 | 5 |
| Size of Wrench Square, inches | 1¼ | 1½ | 2¼ |
| Size and Style of Thread, inches | 8v | 8v | 8v |
| Diameter of Hole Through Joint, inches | 9-16 | ¾ | ⅞ |

The length of box-collar dimensions given in the above table are varied sometimes on the XX rods when it is desired to use a valve larger than regular.

You will find this point discussed under "Hollow Rod Valves."

The large joint used on the 2 inch pipe can also be used on 2½ inch pipe. When used on the 2½ inch pipe, the hole through the valve can be made 1 inch in diameter instead of ⅞ inch as shown in the table.

You will note that the pin on the large joint is 2 inches long, 2 inches in diameter and that the wrench squares are 2¼ inches, thus making the joint as large as some of the smaller cable-tool joints. Thus in setting up this joint, the tool wrenches used are provided with claws the same as cable tool wrenches and a small wrenching bar, built on the order of the one shown on page 15, is used.

As the handling of the large joints is rather slow work, they are not to be recommended unless the holes to be drilled range from 3½ to 5 inches in diameter and the material to be penetrated is very hard. For all ordinary work ranging from 3 to 3½ or even 4 inches in diameter, the next smaller size of joint is to be recommended. The large joints can, however, be used to good advantage in connection with the other joints by using one or two of the heavy rods, fitted with the big joints, in the bottom of the hole and then finishing out with the 1¼ or 1½ inch rods above. By following this plan, it is possible to have a large pin on the bit, this being the point where the greatest strain occurs.

When the threads in a box or on a pin get in such shape that they are dangerous to use, new threads can be cut by cutting off the old joint and then turning a new pin or box. You will note from the table that the collars are made of sufficient length to enable this to be done. If the joints are in such shape that they cannot be re-threaded, it will be necessary to weld on new ends. To do this, the rod should be cut off back of the soft steel. If you are so situated that you can bore out the joints and turn them up, it is better to weld in the ends before they are turned up as it is somewhat easier to make a good weld. However, if you are not in a position to turn up the joint it is better to buy the joints already turned, bored and threaded as then all that will have to be done is to weld it into the rod.

## The Use of a Drilling Weight.

In starting a hole, inasmuch as only one rod is used, the weight is not sufficient to take the stretch out of the rope and thus it is impossible to get a good stroke to the tools. To overcome this difficulty a weight should be bolted onto the swivel stem. Some drillers, in order to make the handling of the rod easy at the start, bolt the weight onto the rod along about the middle, but as this requires the removing of the weight as soon as the hole reaches a depth of 8 or 10 feet, it causes a waste of time, which can be avoided by bolting the weight onto the swivel, at the start.

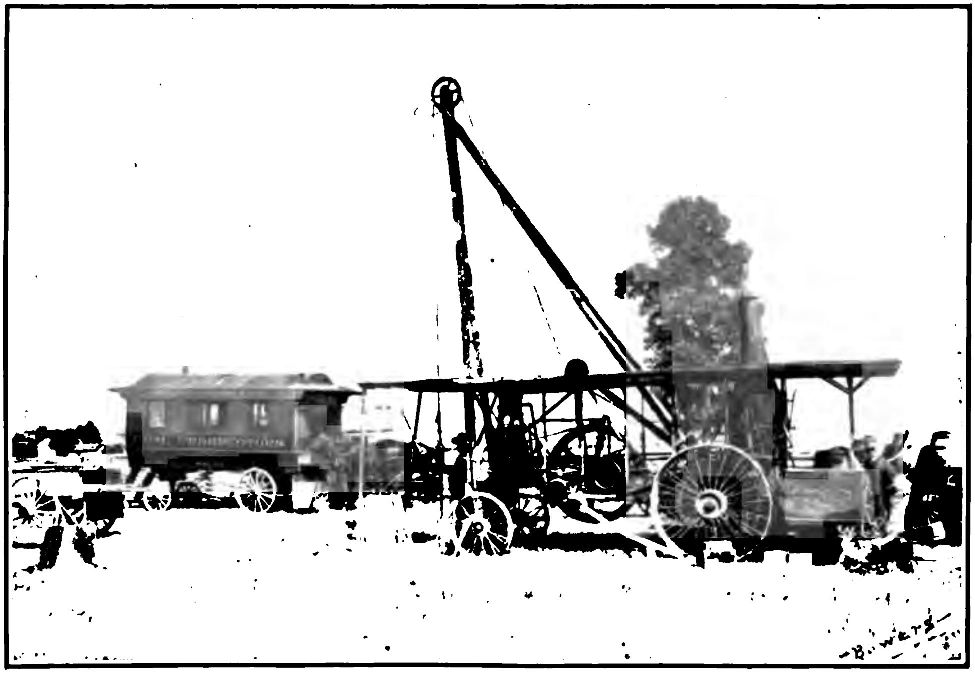
The objection argued against putting the weight on the swivel is that it places the weight so high above the ground that it makes the rods hard to handle. However, inasmuch as it does not take but a few minutes to drill the first few feet of hole, the weight is soon within easy handling distance. In case you have trouble in steadying the rod from below, have your helper go up on the derrick and assist in holding it.

The best size of weight to use is one weighing about 150 pounds and in order to make it easy to handle, it should be made up in two pieces, bolted together.

To prevent the two halves of the weight from crushing the swivel stem when the bolts are drawn up, also in order to make them hold more firmly, they should be provided with grooves down through the center, the grooves being of such depth and diameter that when the two halves are drawn up they come within about one-half of an inch of meeting.

To attach the weights to the stem of the swivel place the bolts through one of the halves, then turn the block on its back so that the bolts heads will be below and the groove above. Next lay the swivel stem in the

Drill outfit mounted on board a scow used in harbor improvement work on Lake Erie.



Hollow rod well drilling and coal prospecting outfit owned by a Michigan drill contractor.

groove, so placing the stem that the upper edge of the lower collar on the stem comes even with the lower edge of the weight. Now slip the other half of the weight down over the bolts, put on the nuts and draw them up as tight as possible.

The cut on the bottom of page 65 shows the drilling weight bolted onto the swivel and illustrates very clearly the method of handling it. The weight shown in the cut is made up of two pieces of cast iron 9 x 8 x 4 inches, the two pieces being bolted together with two one-inch bolts.

In using a drilling weight be sure to keep the nuts drawn up well, especially the lower one, for should the weight slip down over the collar of the stem, the bolts are liable to be broken, due to the heavy wedging strain brought against them.

The depth that can be drilled before the drill weight is removed depends upon the size of rods being used, also upon the style of joints on the rods. When the holes do not exceed 200 feet in depth, it is a good plan to use the weight for the full depth. Even on holes up to 300 or 350 feet when the box-and-pin joints are used, time can be made by using the weight. However, when light rods are being run or even when heavier rods, or rods with box-and-pin joints are being used and the hole is of considerable depth, care must be exercised in adjusting the stroke in order to prevent the joints from breaking down, or the rods from opening up along the weld.

## Starting a Hole with Hollow Rod Tools.

After getting the fittings and fixtures on the machine and after getting the rig set up as explained on pages 3 to 7 inclusive, the first thing to do is to string the drill rope onto the machine.

As stated on page 104, it is the usual custom to use soft-laid rope for hollow rod work, and while the haswer-laid rope will last somewhat longer, still the soft rope is to be preferred on account of its greater flexibility and the greater ease with which it is handled. The amount of rope to use depends upon the height of the derrick. The rope should be of such length that 4 or 5 feet of slack will be lying on the ground when the machine is strung up and one or two wraps are on the drum. It is better to have too much rather than too little rope as a rope which is too short will make it inconvenient in handling the drive weights, drive pipe, etc.

The size of rope to use is governed by the depth to be drilled, also by the size or the rods used. For holes up to a depth of 400 to 500 feet, when the rods used are not larger than 1½ inches, a rope 1½ inches in diameter is of ample size. For holes up to 1000 feet, a rope 1¾ to 1⅞ inches in diameter should be used. For deeper holes, the size of the rope should increase in proportion to depth.

After stringing the cable on machine, the rope hook should be fastened onto the end of the rope. The best way to do this is to splice the hook into an eye as shown in the cut at the bottom of page 204 and the two cuts at the the top of page 205.

Two types of rope hooks are used, the solid hook and the swivel hook. The swivel hook possesses some advantages over the solid hook when handling pipe driving jobs, also when pulling rods, but the writer does not recommend its use on deep work, inasmuch as the solid hook is stronger.

Solid Rope Hook.

The drilling tools to use in starting a hole are drill bit, drill rod, water swivel and drilling weight.

The type of bit to use depends upon local conditions, and the manner in which the pipe driving is handled. You will find these points discussed under "Drill Bits," also "Pipe Driving."

The drill rod used should be one of the 16 foot XX rods, unless the bed rock outcrops or comes within 6 to 8 feet of the top of the ground, in which case a change rod should be used in order to bring the drill weight, which is bolted onto the swivel, down to where it will be easy to handle.

In connecting the bit onto the rod, place a blank valve on top of the bit as explained under Hollow Rod Valves. Now bolt the drilling weight onto the swivel stem as explained under "The Use of a Drilling Weight," and then connect up the drill rods to the water swivel, first, however, packing the water swivel as instructed under "Hydraulic Water Swivel."

Owing to the fact that the discharge hose is not placed on the discharge stem until after the rods have been arranged for pumping, the discharge stem will hammer back and forth against the swivel bail when the hole is started, and in order to get away from this, some drillers take out the discharge stem and leave it out until it is needed. This can be done very easily if the swivel has not been packed, but where it has been packed, care must be exercised in replacing the stem in order to prevent the packing from being pressed out of place.

The stem can also be prevented from hammering back and forth by tying it to one side of the bail and, as this can be very quickly done, it is probably the simplest way out of the difficulty.

Before connecting the joints together, they should be carefully cleaned and taken care of as advised under "Hollow Rod Joints."

In order to make it easy to hoist the tools from the ground, after they are connected up, they should be laid out in front of the hole, and in line with the machine, the same as recommended for cable tools on page 14.

In starting the hole, be sure that the hole comes directly under the bit, when the tools are hanging plumb in the derrick, for should the hole be started out of plumb with the tools, it is liable to drift somewhat. Some drillers, in order to make sure of a proper start, dig down a foot or two with a post hole digger, but if the start is made in soil or clay, this is unnecessary if a little care is taken.

If the start is made in gravel, or ground that ravels, it probably will be necessary to drive a short piece of pipe the first thing. Should this be required, the pipe must be kept perfectly plumb as it is driven. A good way to hold the pipe is to use a pair of pipe clamps as shown on page 42. By bolting the clamps around the pipe until they bind fairly snug and then leveling up under the clamps, the pipe will be driven down straight. Care must be exercised however, in driving the first joint to see that it is not driven onto a boulder, as a boulder, even of small size, will throw the pipe out of line. Should a boulder be struck, it may be possible to drive it out of the road with the tools or a hand spud, but if this cannot be done, it will have to be gotten rid of by some one of the methods recommended on pages 45 to 46. If the boulder should prove to be a large one, it is very probable that time can be saved by shifting the machine and making a new start.

If the hole has to be started directly on the bed rock, or if the bed rock is not more than 3 or 4 feet below the surface, it will be necessary to use some sort of device to guide and steady the lower end of the tools until the rock has been drilled into for at least 4 or 5 feet. The simplest device for this purpose is made by taking a piece of pipe having an internal diameter just sufficient to allow the bit to pass through, and fastening it into the pipe clamp shown on page 42. The length of the pipe used should be about 3 feet. By clamping the piece of pipe firmly between the two clamp timbers and then leveling up under the timbers, the bit will not only be guided and steadied, but the hole will be kept straight. If the bit used in starting the hole has been stoved out to such an extent that the shoulders project quite a little beyond the blade, the shoulders are apt to catch the lower end of the pipe on the up stroke, and thus the tools must be run carefully until the hole has reached such a depth that the up-stroke does not bring the shoulder into the pipe. This trouble can be greatly lessened by fluting out the lower end of the pipe.

The length of stroke to use in starting a hole depends upon the nature of the material to be penetrated. If the depth to bed rock is 60 feet or more, thus necessitating the driving of considerable pipe, it is best to start with a stroke of about 16 to 18 inches as with this length of stroke it is possible, not only to drill faster, but also to drive the pipe to better advantage. If the depth to bed rock is not more than 20 or 30 feet, time can be made by setting the strokes at a point where it would be set for handling the rock work, as the small amount of dirt above the rock can be quickly drilled and the pipe easily driven.

For rock drilling, when the rock is not above medium hardness, a stroke of 12 to 14 inches is usually used down to a depth of 350 to 500 feet.

If the rock to be drilled is of extreme hardness the stroke is usually made less.

In beginning a hole whether in dirt or in rock the tools should be run at rather a slow speed until a depth of 6 to 10 feet has been reached, after which they can be speeded up. If you have never had any experience in handling rod tools it is best to run them about 35 to 45 strokes per minute until they are down about 10 feet, and then gradually increase the speed as the hole gets deeper and you become more experienced in the "feel" of the rods.

It is not an easy matter to give hard and fast rules governing either the length of stroke to use or the speed to run, as drilling conditions vary so greatly in different parts of the country. Another factor which influences the stroke and the speed is what might be termed the individuality of the driller. Thus, one driller will run the tools at a certain speed, with a certain length of stroke and a certain tension on the drill rope and get certain results, while another driller, running the tools in an entirely different manner, will get the same results.

As the aim of every good drill man ought to be to make the most hole at the least cost, you should experiment in the different formations which you drill and find out the best stroke to use, the best speed to run and the best tension on the drill rope to maintain in order to do the work. However, in order to get any benefit from this experimenting you should go about it intelligently, reasoning out beforehand each step that is made.

Another point which you must bear in mind is that a good drill man protects and takes care of his tools and thus, while it should be your aim to make the greatest amount of hole, still you should not carry this to a point where hole is made at the expense of broken tools.

In starting a hole in dirt, the procedure is practically the same as that for cable tools described on pages 24 and 25. That is the hole is drilled down without the use of water as far as it will go and then water is added to make a sludge.

When the sludge begins to get thick, the tools should be pulled and the hole bailed out. The bailer furnished with hollow rod outfits is about 5 or 6 feet long and is of the flat-valve type. The flat valve is used owing to the fact that the bailer is of small diameter and thus any other type of valve would not prove efficient.

As under most conditions it is possible to start the rods to pumping as soon as the hole is down 18 to 20 feet, the bailer is usually worked by hand, thus permitting of the bailer being laid to one side and out of the way after the work gets started.

For handling the bailer by hand the best line to use is a one-half inch or a five-eighth inch manila rope.

As the smaller bailers used in hollow rod work are so light that they will not sink into the sludge, they are usually used below a sand pump "Sinker."

A sinker is made up of a rod about 5 feet long by about ⅞ inches in diameter. The upper end of the rod is flattened, a hole drilled through and a link passed through the hole. This link is about 5 inches long and into it is fastened the sand line. The lower part of the sinker rod is forged down and bent back so as to form a slot about 5 inches long and ¾ of an inch wide. The upper part for the slot is open so that the bail of the sand pump can be slipped down into it. After the bail has been placed in the slot the opening is closed by driving the open side up against the main stem. The advantage of having the slot on the sinker is that in case the sand pump becomes fast it provides a means for jarring it loose, inasmuch as the slot will work on the same principle as a set of drill jars.

Under some conditions time can be made by punching the hole down as far as possible without putting any water in the hole and then placing a 10 or 15 or even a 20 foot piece of pipe, depending upon how far the hole can be punched down, in the hole and driving it down. When this can be done it is unnecessary to use the sand pump as the pipe can be filled with water and the rods started to pumping. As a rule this method can be followed to advantage only when the material above bed rock is of a loose, porous nature, or when the bed rock does not lie many feet below the surface.

As a usual thing, it is best to drill the hole as deep as possible before starting the drive pipe, as the hole will be larger in diameter and thus when it does become necessary to set the drive pipe, it will drive easier.

## Turning the Tools.

As explained under cable drilling, page 25, it is necessary to turn the tools in order to cut the hole round and keep it straight. What is said regarding the turining of cable tools applies to the turning of rod tools with the exception that, instead of turning the rod tools first in one direction and then back again, as the cable tools are turned, they are always turned in one direction. With ordinary drill rods, having right-hand threads, the direction should be to the right. The reason for this is that by turning the tools to the right, the motion tends to set up the threads closer, thus keeping the joints tight.

When the tools are fitted with box-and-pin joints, the necessity for turning them in one direction only is not so great, owing to the fact that these joints are held by the friction of the shoulders and not by the binding action of the threads. However, with coupling joint tools, it is very important to turn them in a right hand direction only, and especially is this so when rock is being drilled.

For turning the rods, a handle is usually bolted onto the stem of the swivel, unless a drilling weight is being used, in which case the weight will serve as a handle. Some drillers use both the weight and the handle, bolting the handle onto the swivel stem just above the collar and then bolting the weight on above handle. It has been the writer's experience that it is easier to handle the tools with the weight, than with the handle and thus, unless the hole is too deep to use a drilling weight, he never attaches the handle. One of the main objections to the handle is that it is liable to slip out of the driller's hands and fly around and strike him on the hands or arms or even in the face. By using the weight it also makes it easier to keep the joints tightened up. To use the weight for this purpose, give the tools a quick spinning motion in the right hand direction, just as they start on the down stroke. As the rotation of the bit will be instantly stopped as soon as it touches the bottom, the momentum of the drill weight will be such as to throw a strong twisting strain throughout the full string of rods, which will thus tend to set up the joints. In fact, so strong is this twisting action that care must be exercised in using it, when drilling with one-inch rods or when the hole is of considerable depth, as it may cause some of the rods to open up along the weld.

Drill Handle.

The efficiency of the above method is not very great when drilling in dirt, as the rotation of the bit is not arrested quickly enough to utilize the momentum of the weight, but when drilling in rock, and it is in this drill- that the joints are most apt to come loose, it is very effective.

## Arranging the Outfit for Pumping.

As soon as the hole reaches a depth which will allow the tools to be arranged for pumping, it is best to at once prepare the outfit for operating in this manner, as in the large majority of cases better time can be made by making the tools self-cleaning at the earliest possible moment.

First pull the tools from the hole and then, by using the sand pump, carefully clean out all of the sludge. Especially it is necessary to remove all of the sludge if the hole is passing through a band of clay, as the bottom of the hole for a distance of 3 to 4 feet, will probably be plastered with "clay balls," which are liable to pack against the sides of the bit as the tools are lowered into the hole. Should this occur, the side holes in the bit are liable to be "mudded up" before the bit gets a chance to begin to work. Next unscrew the bit from the rod and substitute for the blank valve a plate-and-ball valve. Before putting valve on the bit however, the side holes of the bit should be carefully cleaned, and it is also a good plan to examine the hole in the bottom of the drill rod to see that none of the sludge has worked up past the blank valve and become packed in the rod.

In order to take care of the sludge which is pumped by the rods, also in order to make it possible to use the same water over and over again, a tank should be provided, into which the sludge can be discharged. The tank should be tapped about middle way of its height and a three-quarter inch nipple securely fastened into it. In operation, the discharge hose from the swivel conducts the sludge into the tank where the heavier cuttings settle and then the water passes back to the drill hole through a return hose which is fastened onto the nipple at the side of the tank.

On account of the readiness with which it can be secured, also on account of the ease with which it can be handled, a coal oil barrel is generally used for the tank.

The discharge hose which carries the sludge from the swivel to the tank should be about 8 to 12 feet long, with an inside diameter of 1 inch. As this hose has to stand a large amount of knocking around, it should be of the very best grade and of 9-ply thickness.

In order to prevent the discharge hose from threshing around and getting in the way of the driller, also in order to protect the hose from wear, means must be provided for so fastening it that, while the tools will be allowed to work freely, still the hose will be so held as to be protected from wear and also be out of the way. One of the simplest and surest methods of doing this is as follows:

Secure a piece of heavy, tough belt lacing about 36 inches long and fasten it securely around the hose about 2 feet from the end which goes over the discharge stem. In fastening the lacing, wrap it around the hose 4 or 5 times, starting the wraps about 4 inches from one end of the lacing, and then, after drawing it up tight, tie it so that it will hold fast. This should leave one end of the lacing about 16 inches long extending out beyond the knot. Next cut a slot 2 inches long in the lacing, about 4 inches from the end.

After arranging the hose as above, secure ten small screw hooks and, beginning 4 inches from the bottom of the left-hand derrick leg, screw them into the leg, spacing them 6 inches apart. When drilling, the hose is held by slipping the slot, in the end of the lacing, over one of the hooks, the hook to use depending upon the position of the water swivel. Thus, when putting on a new change rod, one of the upper hooks will be used and then as the hole gets deeper the lacing is transferred to the next hook and so on.

The left leg of derrick referred to above is the one which would be on the left hand side if you were standing out past the hole and facing the machine.

In order to steady the end of the hose which goes into the barrel, it can be tied to a nail driven into the upper end of one of the staves. Some drillers fasten the hose to a stick which is nailed against the side of the barrel and which extends 2 to 3 feet above the top of it.

In handling the hose while drilling, care must be taken to prevent it from becoming kinked as a kink will not only stop the sludge from discharging, thus causing it to be forced up through the packing, but it will also cause the inside lining of the hose to break down and this will later cause trouble by peeling off and stopping up the hose. When the lining of the hose once breaks down, the gritty sludge soon eats into the canvas and totally destroys the hose.

Especially is it necessary to prevent the hose from becoming kinked when the tools reach the top of the up stroke, as it is at this point that the heaviest discharge begins. This is due to the fact that the upward stroke of the tools gives a momentum to the sludge in the rods and this momentum causes the sludge to rush out through the discharge hose the instant the rods stop and start on the down stroke. Should the hose be sufficiently kinked or any other cause arise to prevent the escape of the sludge, the sludge in the rods will tend to acquire a downward momentum, on the down stroke, and this will in return retard the entrance of the sludge through the bit.

On the other hand, if the sludge is allowed free passage through the discharge hose, it begins to rush out the instant the tools reach the top of the up stroke, and as this forms a vacuum in the rods it makes the ingress of the sludge through the holes in the bit much easier. Thus by keeping the discharge unobstructed, it not only makes it easier for the sludge to escape, but also assists in drawing into the rods the largest possible amount of sludge at each stroke.

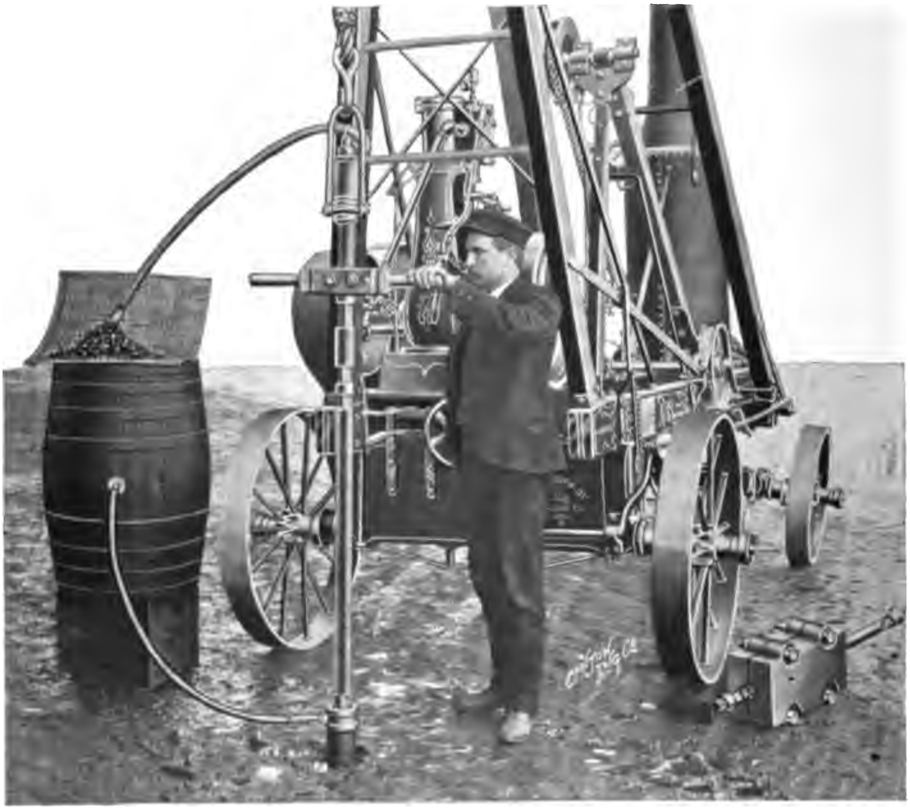
The description of the action of the sludge in the rods, made above, taken in connection with the description given under "Drill Bits" beginning on page 249, will give an idea of the forces at work in making drill rods pump.

The cut on the following page shows how an outfit can be arranged for pumping after the drive pipe has been started into the hole. The same method can be employed for handling the work before driving any pipe, excepting of course, the return hose will discharge directly into the hole instead of being connected onto a tee.

You will note that the cut shows a screen on top of the barrel, onto which the cuttings are being discharged. A screen is often employed in coal prospecting work when drilling through the coal, but is rarely used in water well work. Should you desire to test or sample any material through which you are drilling, it can be done by allowing the sludge to discharge into a bucket and then after giving it sufficient time to settle, pour off the excess sludge and water and wash the cuttings.

When using hollow rod tools by the self-pumping or hydraulic method, it is necessary to keep the hole pretty well filled with water, the amount of water to use depending upon the nature of the material being drilled. As a general rule, unconsolidated deposits are harder to pump than rock and thus when the rods are first arranged for pumping, the hole should be filled nearly to the top.

After filling the hole with water, the barrel should be filled until the water just begins to run out through the discharge hose. By bringing the water in the barrel up to this point it will run back into the hole just as fast as it is pumped out and thus the amount of water in the hole will remain constant, except for that which leaks out. This leakage can be made up by pouring additional water into tbe barrel from time to time.



The length of time which one barrel of water will last depends upon the material being drilled. Material like clay or some of the shales which thicken rapidly, may require a new barrel or rather a new half barrel of water every two or three hours, while in drilling certain limestones and sandstones, one filling of the barrel will last for a day or two. If you are in a region where water to drill with is hard to get, it is a good plan to have two barrels for discharging the sludge into, as one barrel can be used until the sludge is too thick to handle well and then this barrel set aside and the other barrel used. By the time the sludge in the second barrel becomes too thick to handle, the cuttings in the first barrel will have settled and then the water can be drawn off, the cuttings removed from the barrel and the water returned thereto, with the least possible loss.

Generally when drilling in sands and gravels and often times when drilling in rock, the hole will "bleed" a small amount and thus it can be so arranged that more water will be pumped from the hole than returns to it. Under such circumstances this excess water can be stored, thus making it possible to cut down the amount needed from the outside. When the "bleed" is considerable, it may be sufficient to not only take care of the hole, but also to furnish water for the boiler or for other purposes.

As previously stated, the rods pump best when the hole is fairly well filled with water, but only in hard-pumping material it is absolutely necessary to use a large quantity of water. In fact, in certain clean-cutting rock formations, such as sandy shales, clean sand stones and limestones, it is best to limit the quantity of water in the hole in order to lessen the force with which the sludge is discharged, thereby making it easier to hold the packing in the swivel.

It is impossible to give an inflexible rule covering the amount of water to use in the hole as so many factors enter into this consideration. However, the pumping efficiency of a set of tools correctly made and skillfully operated is much greater than is ordinarily supposed. The writer has experimented somewhat along this line and has found that when drilling a 2½ inch hole and cutting a clean, sandy, shale he was able to get good results at depths and with amounts of water as follows:

| Depth of Hole. | Amount of Water in Hole. |
|---|---|
| 75 feet | 4 feet |
| 200 feet | 8 feet |
| 350 feet | 12 feet |
| 500 feet | 20 feet |

The above results were obtained under favorable conditions and thus should not be considered as standards to govern drill work. The figures are given simply to show that it is unnecessary to have a hole full of water in order to make the rods pump.

There is now another point to be considered regarding the amount of water to use, this being the buoyant effect of the water on the rods. Where a hole is not over 100 or 200 feet in depth, the weight of the tools is not sufficient to put a dangerous strain upon the rods, or the joints, unless a long stroke is used and the tools are being run on hard material. However, as the hole gets deeper, the total weight of the rods becomes greater, and thus the strain on the rods in the bottom of the hole mounts up rapidly. To overcome this heavy strain, the stroke is shortened as explained on page 245, but even with the shorter stroke, when holes of great depth are being drilled, the strain on the tools in the bottom of the hole becomes destructive unless the weight of the string of rods is partly buoyed up by a column of water in the hole.

It sometimes happens that a crevice is struck which drains all of the water from the hole. If this occurs when the hole is of considerable depth, it will be necessary to hold a somewhat stiffer tension in the drill rope and also run the tools at a slightly slower gait in order to protect the rods. Unless the crevice is of considerable size, the cuttings from the drill hole will soon plug it. After drilling 2 or 3 feet beyond the crevice, pour several buckets full of water in the hole to see whether or not the crevice has been sealed. If the hole holds water, the drill work can then go on as it did before the crevice was struck.

In case the hole is of considerable depth and does not hold water, it is usually a good plan to attempt to seal the crevice. To do this remove the drill rods from the hole and pour into the hole a thick batter of clay and water. There should be enough of the batter to fill the hole up past the crevice for a distance of 3 to 4 feet. Now remove the plate-and-ball-valve on top of the bit and substitute a blank valve and after lowering the tools into the hole, churn them up and down, thus puddling the clay into all of the cracks and crevices. After operating the tools for about ten minutes, slowly pour water into the hole until the clay has about 50 feet of water on top of it. By adding the water, the pressure on the clay is increased and thus the clay is forced further into the openings. Continue puddling the clay, after the water has been added, for about five minutes, and then remove the rods, exchange the blank valve for a plate-and-ball-valve and proceed with drilling operations.

In order to prevent the bit from clogging, when first lowered into the hole, it should not be lowered deeper than the top of the clay before the tools are put to pumping. Gradually lower the tools as the clay is pumped out and when the hole is clean, drill work can be continued the same as before the crevice was struck.

If the hole which you are drilling is for prospect work, or if it is for water, and you know beforehand from your familiarity with the territory, that the water will not rise as high as the crevice, then there is no necessity for stopping the leak, for as soon as the hole is drilled a short distance beyond the crevice, the rods will again pump and the work will go on as before. However, if you are drilling for water and the water when struck will rise above the crevice, it is best to seal it in order not to allow the water to escape. If you are drilling for flowing water, it is absolutely necessary to stop all crevices or else re-case the hole if the best flow is to be obtained. If the clay method advocated above does not prove effective it may be possible to plug the crevice by washing sawdust, bran or oats into the open spaces and then closing them up with the clay. Should all of these methods fail, it will be necessary to cement the hole as explained on page 48.

## Driving Pipe.

While the methods employed in handling pipe driving jobs with hollow rod outfits are somewhat different from those used with cable tools, still what is said on pages 29 to 42 inclusive, in the cable tool section regarding protecting the lower end of the pipe, also kinds of pipe to use, as well as different methods to use in connecting up the pipe, etc., applies to hollow rod work as well as to cable work, and thus these pages should be carefully read.

With hollow rod tools it is generally possible to drill much deeper before setting the pipe, than can be safely done with cable tools. This is due to the fact that the rods are continuous from the bottom to the top of the hole and thus even though the hole should cave in on the tools, they can be recovered. As the hole will be larger, if drilled without drive pipe, it is generally best to drill as deep as possible before starting the pipe into the hole, as the pipe will go down easier, when finally it does become necessary to drive it. Especially should this advice be followed if a long line of pipe has to be driven.

Another advantage gained by drilling the hole as deep as possible before driving the pipe, is that long lengths can be driven thus making the cost of pipe much less than if the shorter lengths were used. Not only do the longer lengths cost less, but in case hard driving is encountered further down they will drive easier, due to the fact that there are fewer couplings in the hole. As the hardest driving is usually towards the bottom, it is best to have as few couplings as possible at that end of the line. A line of drive pipe made up of full-length pipe will also be somewhat safer on hard driving work, inasmuch as the fewer the couplings in the hole the fewer the chances for the pipe to break down at the joints.

The depth it will be possible to drill before driving the pipe depends largely upon the nature of the material being penetrated. When drilling in certain kinds of clays it is possible to drill several hundred feet without driving any pipe, as the rubbing up and down, and the hammering back and forth, of the drill rods against the walls of the hole, seem to pack them so that they stand firm. On the other hand, when sand or gravel is penetrated, it is very rarely that the walls can be made to stand and thus time can usually be made by driving pipe as soon as either of these ravelly materials is encountered.

The pipe driving device used in hollow rod work is shown on page 185. As explained on page 184 this device is also used in pulling pipe. The only difference between the two operations is that in pulling pipe the stroke is so adjusted that the pulling plug is struck on the up stroke by the jarring head, while driving pipe, the stroke is so adjusted that the driving weight strikes the plug on the down stroke. Thus when using this device the pipe can be driven either down or up simply by varying the amount of drill rope let out.

The cut on the opposite page shows the outfit hooked up ready for business.

The weight of driver to use on rod work depends upon the size and amount of pipe which will be driven. For all ordinary work the driver need not weigh over 300 pounds. In fact a great many pipe driving jobs can be handled by a driver not exceeding 150 pounds in weight. On some work, however, it is necessary to use a very heavy driver and when such work arises, the weight of the driver can be increased by bolting more sections onto the driver stem. As a rule the most convenient size of section to use is one weighing 150 pounds, that is, each separate weight will weigh only 75 pounds but the two weights which go together to make a pair or section will weigh 150 pounds. By having the weights divided up into the 75 pound pieces it makes them more convenient to handle, and it also makes it possible to use the sections interchangeably with the drilling weights, in case one of these weights should become broken.

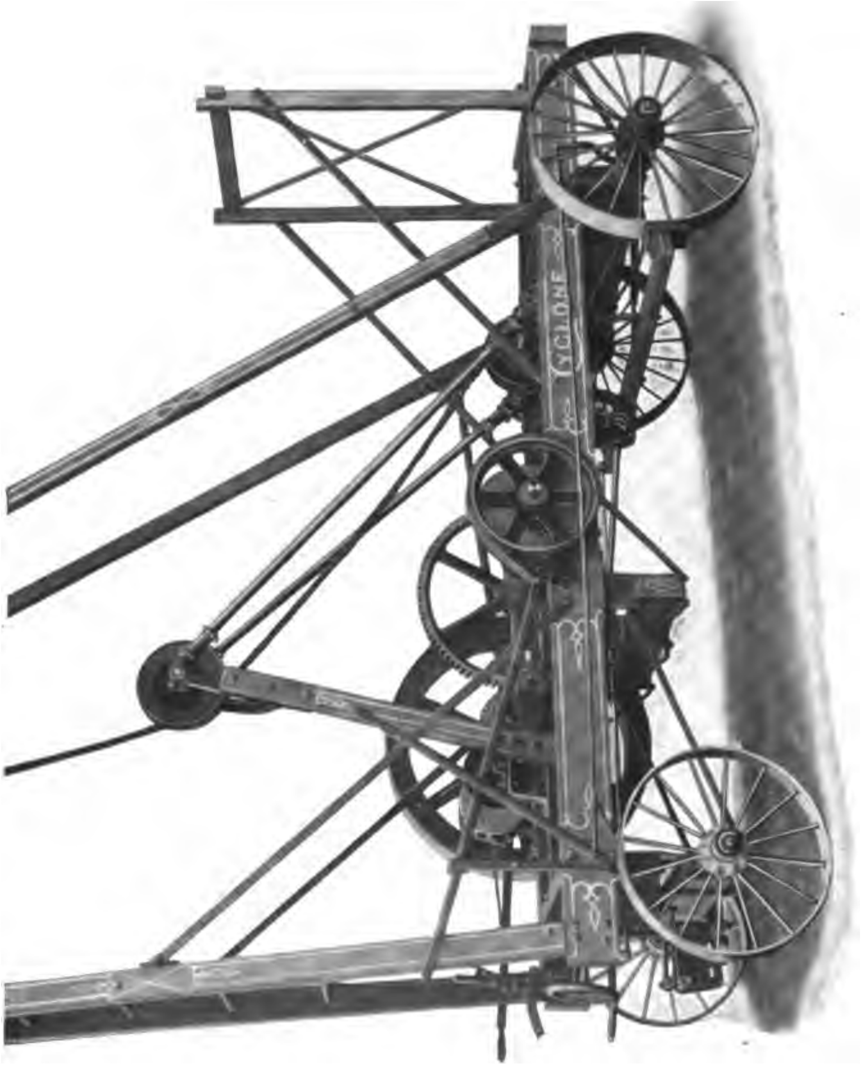
Some drill manufacturers make a drive weight having the lower part filled in with wood, so that in driving, the wood, and not the iron comes in contact with the drive plug, or the drive head. This sort of a weight is of some advantage when an uncontrolled type of spudder is used, owing to the fact that the wood protects the upper end of the pipe, but it is of no benefit when used on a machine having a good spudder inasmuch as with a spudder which can be controlled, the force of the blow delivered can be so regulated that trouble will arise only when the tools are carelessly or ignorantly handled.

The driver stem on the driving and pulling device is made of the very best grade of XX pipe. The lower end of the stem on which the jarring head is screwed, is threaded back a sufficient distance to allow a XXX coupling to be screwed on full length.

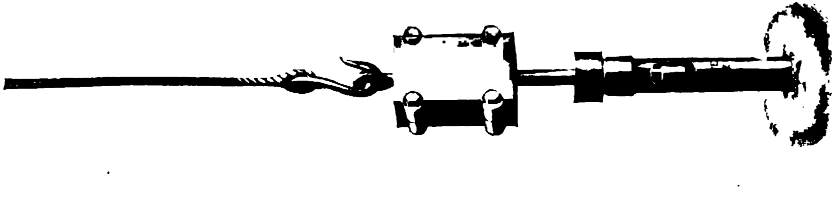
When it is desired to drive a different size of pipe the XXX coupling is unscrewed, the old pulling-and-driving plug slipped off and a plug of proper size slipped on, after which the coupling is again screwed onto the stem.

When the pulling-and-driving device is to be used for handling extremely heavy pipe pulling work the stem should be cut longer than the ordinary length and should be made of solid steel. The jarring head on the lower end of driver stem should also be made of steel and should be longer and heavier than a XXX coupling.

In handling a pipe driving job where the hole has been drilled to a considerable depth before starting to drive, it is very likely that the first



Hollow Rod Outfit Arranged for Pulling or Driving Pipe.



three or four lengths of pipe will slip down without much driving. If such is the case the pipe clamps shown on page 42 should be set over the hole and when the lower edge of the upper coupling of the piece being driven comes within an inch or two of the top of the clamps, they should be tightened up to prevent the pipe from slipping down into the hole, while the next joint is being screwed on.

If the hole is of such size that the pipe can be lowered without having to be driven, there is no need of using a pipe driver and the work can then be handled by some one of the methods described under "Re-casing a Hole," page 187. In those regions where holes can be drilled to a considerable depth before driving pipe, it is best to use a bit which will cut a hole somewhat larger than the outside diameter of the coupling on the drive pipe as this will allow the pipe to be lowered without driving. As pipe can can be lowered into a hole much faster than it can be driven into it, time will be saved.

In case it is necessary to drive the pipe, and long lengths are used, it can be handled best by attaching it to the driver before the pipe is hoisted from the ground. To do this lay the driver flat on the ground with the driver stem in line with the middle sill of the machine and pointing away from it. Now slip the pipe over the driver stem and screw the plug into the coupling of the pipe. If the pipe being driven is 3 inches or larger in diameter, it should be pulled back on the stem until the plug is drawn against the jarring head, for should there be any slack between the jarring head and the plug, the pipe will slip back, the amount of this slack, as it is being hoisted.

Should the slack be left between the head and the plug and the stem bind in the plug, the pipe is liable to be hoisted to a nearly vertical position before the slip takes place and should this occur, the pipe will drop the distance of the slack and this might result in injuring the man handling the tools.

You will note in the above that you are instructed to lay the pipe driver so that the stem of driver comes in line with the middle sill of machine. This is for the purpose of bringing the pipe in line with the center of the derrick so that when the driver and pipe are hoisted, the drill rope will travel in line with the crown pulley thus preventing the rope from slipping off to one side. On account of local conditions it will sometimes be impossible to arrange the driver and pipe as instructed, and where such conditions exist, care must be taken to see that, as the driver is hoisted, it is kept shoved up so that the rope will not be pulled with too great a force against the side of the crown pulley.

In calculating the amount of pipe to be driven, it should be so figured that the top of the pipe does not extend more than 1 or 2 feet above the surface of the ground, when the pipe has been driven as far as possible.

The reason for this is that a greater height will make it inconvenient to return the water to the hole when drilling operation are started. Under some conditions it is necessary to have the pipe extend several feet above the ground, but these are special cases and will be discussed further along.

After driving the pipe as far as possible, the driver should be laid to one side and the hole filled with water to within 15 or 20 feet of the top. Next lower the tools into the hole, rig up the discharge hose and the return hose and proceed with the drilling operations. If the pipe has had to be driven, there will be a plug forced up into it and this plug will have to be drilled through before the end of the pipe is reached. If the pipe has not required very hard driving, the plug may not be solid, and if such is the case the tools, when first lowered into the hole, should be let down very carefully for the last 3 or 4 feet so as to prevent the loose clay and dirt, which has been shaved from the walls, from stopping up the holes in the bit. By keeping a "feel" on the rods it is possible to tell the condition of the sludge in the bottom of the hole, and when the "feel" indicates that the sludge is very thick, the bit should not be forced into it. The better plan is to stop the tools at the top of the sludge and then drill down through it.

After the plug has been drilled out, the hole should be continued on down as far as possible below the pipe, as the further ahead it is possible to drill, the longer the length of pipe which can be driven. Another advantage of drilling ahead is that the hole will be somewhat larger, due to the oscillation of the rods, and thus the pipe will drive easier.

When the hole reaches such a depth or material being penetrated is of such a nature that you are unable to drill sufficiently far ahead to drive a full length piece of pipe, time can be saved and money made by using shorter lengths.

As a rule these shorter lengths are cut about 4 or 5 feet long. Where especially hard driving conditions have to be handled the lengths are sometimes made as short as 2 or 3 feet. These very short lengths, however, should not be permitted to remain in the hole and, if the driving conditions are such that a considerable amount of pipe will have to be driven, even the four-foot lengths should not be allowed to remain in the hole, as money can be saved by using joints as long as possible, due to the fact that the cost of pipe per foot increases considerably as the lengths are made shorter.

For handling a hard pipe driving proposition, the driller should be provided with joints of pipe of several different lengths, the most convenient lengths being 2, 4, 6, 8 and 10 feet. By having these various lengths it is never necessary for the top of the pipe to be over a foot or two above the surface of the ground, inasmuch as the two-foot piece can be driven down first, then this piece unscrewed and the four-foot piece put on and driven down, then the four-foot piece unscrewed and the six-foot piece put on and driven down, etc. In order to make it possible to unscrew the different lengths after they are driven, it is necessary that the hole, when first started, be drilled quite a little larger than the outside diameter of the couplings on the drive pipe. Thus if three-inch drive pipe is being used the hole should be at least 4½ inches in diameter down to a depth of 12 to 15 feet. If the upper part of the hole is through material which is liable to ravel or cave, or even if the material is a firm clay which will stand well, and considerable hard driving will be encountered, it is best to set a piece of casing at the top. The length of the piece of casing to set depends upon the length of the longest piece of drive pipe which will be driven. As a rule, on hard driving work a ten-foot piece of pipe is the longest used, and thus the piece of casing to be set need not be over 12 or 15 feet long. The internal diameter of the casing should be of such size that the couplings on the pipe will readily slip down through it. On three-inch work the casing should be at least 4½ inches, other sizes in proportion.

In handling a pipe driving job by the above method the length of the piece of pipe put on depends upon how far the pipe can be driven. If you are in material which will not allow more than a foot or two of driving, then the two-foot piece should be put on and driven down as far as possible. If it is possible to do so, this piece should be driven down until the bottom of the coupling comes within two or three inches of the top of the coupling on the large pipe. If this cannot be done, then it will be necessary to drill out the hole and drive again.

After the two-foot piece has been driven down as far as it should go, the hole should be drilled as far ahead as possible, then the two-foot piece unscrewed and a 4, 6, 8 or 10 foot piece screwed on in its place. The length of the piece of pipe to use in place of the two-foot piece will be determined by the depth it is possible to drill ahead or by driving capacity of the material being drilled. If you are unable to get ahead with the hole or if the material drives "mean," then a four-foot piece should replace the two-foot piece. The procedure to follow out with the four-foot piece is the same as with the two-foot. After the four-foot piece has been driven, the hole is drilled ahead, the four-foot piece unscrewed and a 6, 8 or 10 foot piece screwed on in its place. The above method is followed out until a ten-foot length is in the hole. The ten-foot piece is allowed to remain and if you are still in hard driving, the two-foot piece is screwed onto the ten-foot piece and the work continued as described above. It may be that after 8 or 10 feet of hard driving it will be possible to drill ahead, or the material will so change that the pipe will drive easier, and under either of these conditions it is best to use as long a length of pipe as can be conveniently handled.

In screwing on the 2, 4, 6 and 8 foot lengths of pipe, the threads should be liberally oiled and the joints set up just a little looser than on the long lengths, owing to the fact that the short lengths will have to be unscrewed while the joint is down in the hole, and thus this joint must be so set up that it will come unscrewed, rather than the joint lower down. In screwing on the ten-foot piece, however, it should be set up as tight as possible, inasmuch as this length will go down into the hole.

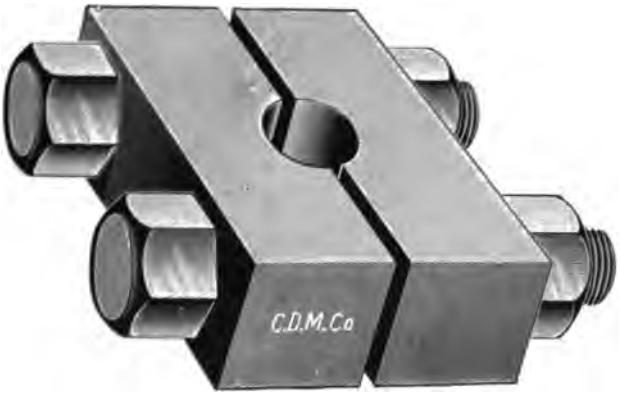
When handling a pipe driving job by the above method, the outer or larger casing must be left in the ground until the drive pipe has been seated in the rock, after which it can be pulled, and saved for the next job. Some drillers use the above method for handling full, twenty-foot lengths of pipe through hard driving, but inasmuch as this requires the driving, of a twenty-foot outer casing, and also requires the connecting up of joints down 18 to 20 feet in the hole, the writer does not consider it a paying proposition. The writer's reason for this opinion is based on the fact that the difference in cost between ten-foot and twenty-foot lengths of pipe is not sufficiently great to justify the time lost in connecting up joints down so far in the hole nor in constantly having on hand the extra number of pieces of pipe necessary for carrying the work down to a depth of 20 feet.

In all of the pipe driving methods covered by the foregoing pages, the regular pipe driving device shown on page 185 is used, and thus each time the pipe is driven, the drill rods have to be removed from the hole and then after each driving operation is finished, they have to be again let down into the hole. As this handling of the rods consumes a considerable amount of time, especially when the hole is rather deep or when the pipe driving conditions are such that only a small amount of pipe can be driven at one driving, speed can usually be made by driving and drilling at the same time.

To drive and drill at the same time a weight or driver is bolted onto the drill rods at such a point that, when the bit is striking on the bottom of the hole, the driver is striking on top of the pipe. Thus if the top of the pipe extends 3 feet above the ground, the driver should be bolted on so that the bottom of the driver will be just 3 feet above the ground when the bit is on the bottom of the hole. When drilling by this method good judgment must be exercised, for should the hole drill out faster than the pipe drives, the full weight of the rods will fall upon the upper rod couplings at each blow and if the hole is above 80 or 100 feet in depth, the strain may become violent enough to pull the rods apart at the joints. Should the pipe tend to drive faster than the hole drills, the danger is not so great, unless a very deavy driver is being used. In case the driver is too heavy and the pipe goes down faster than the hole, the strain on the rods may be sufficient to kink them.

When drilling and driving at the same time, it is best to use pipe cut in four-foot length as this length corresponds with the length of change rods and thus it will be unnecessary to move the weight after it is once bolted on. The best place to fasten the weight is on the swivel stem at the same point that the drilling weight is fastened. In fact, the drilling weight is often used as the driver, when drilling and driving at the same time. Should the conditions be such that the weight when bolted onto the swivel stem, does not come at the proper point for striking the top of the pipe when the bit is on the bottom of the hole, and should you not have a piece of proper length to make the weight come just right, then the weight will have to be bolted down on the change rod.

Besides the drilling weight referred to, there is also another type of driver used in handling the above work, this driver being made of soft steel blocks 4 x 4 x 10 or 12 inches. The accompanying cut shows its construction. As this driver weighs only about 90 pounds and as it is so shaped as to be more convenient to handle than the drilling weights, it is to be preferred, when the work is of such nature that the driver will have to be changed very often.



Hollow Rod Drive Clamps.

In order to be able to return the sludge to the hole when drilling and driving at the same time, the barrel into which the sludge is discharged, should be elevated about 3½ to 4 feet above the ground so that the nipple, to which the return hose is attached, will always be above the top of the pipe. The return hose will have to be a little longer than the one generally used and the top of the drive pipe will have to be fitted witn a maleable or steel tee, into which a ¾ inch nipple can be screwed. By slipping the return hose over the nipple in the barrel, also over the nipple in the tee, the sludge will be returned to the hole during the entire drilling and driving operation.

There are many other methods of taking care of the sludge proposition besides the one referred to and it may be that, owing to local conditions, you will be able to work out a better plan, but inasmuch as the the elevating of the barrel is a simple and positive means of handling the job, it is to be recommended for general work.

One of the main advantages of drilling and driving at the sane time is that rods do not have to be removed from the hole each time a new piece of pipe is driven. The work can be handled as follows, when four-foot lengths of pipe are used and when the driver is bolted onto the swivel stem. First disconnect the return hose from the nipple in the tee, and then unscrew the tee until it is loose from the pipe. Next hoist the rods until the joint between the swivel and the first rod comes about one foot above the top of the tee. Hold the rods at this point by passing the foot-wrench under the joint, or by using Brown's tongs, or holding tongs. In putting the holding device on the rods, first lift the tee and then place the device on the rod below the tee, thus carrying the weight of the rods on the top of the pipe, and allowing the tee to rest upon the tongs or whatever device is used for holding the rods. Next unscrew the swivel from the rods and hoist it until the bottom of the swivel stem comes about 5 feet above the ground. Next connect a four-foot change rod onto the top of the rod extending out of the hole, first, however, removing the tee which has been unscrewed from the pipe and which is resting on the holding tongs

After setting up the joint on the change rod, screw the tee onto a four-foot length of pipe, and then slip this piece of pipe down over the change rod, which has just been connected up. In slipping this piece of pipe over the rod see that the end of the pipe with the tee on is at the top. Now lower the swivel down on top of the change rod and connect up this joint. Next hoist the rods until the strain is taken off of the holding tongs, after which remove the tongs from the rods, screw the four-foot piece of pipe onto the top of the drive pipe, atttach the return hose to the nipple in the tee and you are again ready to begin drilling and driving.

The methods ontlined above will have to be varied somewhat when the driving weight is not bolted onto the swivel stem or when the pieces of pipe used do not correspond in length with the change rods. However, the general plan followed under all conditions is practically the same as that outlined.

When driving pipe either by the straight driving method or by drilling and driving, the pipe tongs should be placed on the drive pipe and the pipe set up from time to time, as the constant hammering tends to loosen the joints and a loose joint may cause the threads to strip on hard driving.

When seating drive pipe in the rock, the instructions given on pages 46 to 50 should be followed out. After the pipe has been seated in the rock, it is a good plan to screw a short, fluted or funnel shaped nipple into the top coupling, as this will prevent the joints on the rods from hanging up on the top of the pipe during drilling operations. Especially is the fluted nipple an advantage when box-and-pin-joint rods are used.

## Hoisting Drill Rods.

As the time occupied in hoisting drill rods is dead time, the rods should not be hoisted more often than is necessary, and then when it does become necessary, the work should be gone through with in the least possible time.

In hoisting it is best to hoist two or more rods at a time, for by so doing the time consumed is brought down to the minimum. Another advantage is that the number of joints unscrewed is less and thus some of the trouble of the joints coming loose in the hole is done away with, inasmuch as the fewer times a joint is unscrewed, the better will it hold.

The number of rods which can be pulled at one time depends upon the height of the derrick. On machines of ordinary size, the derrick is usually from 22 to 27 feet high and thus two rods are pulled at one time.

While the general methods used in handling the coupling-joint rods and the box-and-pin-joint rods are very similar, still there is a difference in some of the appliances used and thus the methods will be discussed separately.

We will first take up the hoisting of the coupling-joint rods.

When beginning hoisting operations, the swivel should first be unscrewed from the rods and then laid to one side so as to be out of the way. In unscrewing the swivel, be sure to have the swivel stem unscrew out of the coupling, thus leaving the coupling on the drill rod. This same advice applies to the unscrewing of any coupling joint along the line of rods as any rod taken off should be unscrewed from the coupling. The reason for this is that it makes it easier to again to connect up the rods and also makes it safer in the handling of the rods. The main advantage, however, is that it makes it possible to use a very simple and effective tool, namely the grab hook, in the hoisting of the rods.

Grab Hook.

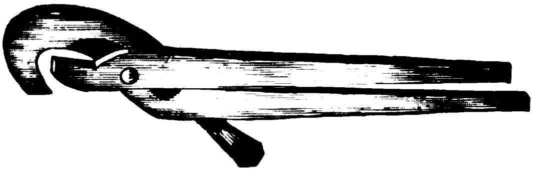
Swivel Grab Hook.

Two types of grab hooks are used, namely the stiff hook and the swivel hook. The stiff hook is the cheaper of the two but the swivel hook possesses a slight advantage which in some respects makes it more satisfactory. Thus in hoisting rods with a swivel hook, the drill rope can twist around without causing the rods to wind around the rope or without causing them to be thrown out of line.

In order to be able to bring the grab hook back to the ground after a rod has been hoisted, the hook is provided with an eye into which should be fastened a piece of one-half inch rope. The length of rope depends upon the height of derrick, but for derricks of ordinary height, the length need not exceed 20 feet.

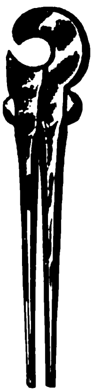
After removing the water swivel from the rods as instructed above, place the grab hook onto the rope hook and then slip the grabs of the hook under the the coupling on the top of the drill rods.

Next throw the hoist into gear and elevate rods until the next joint comes above the surface. Hold the rods at this point by placing a pair of Brown's tongs on the pipe and driving a pipe coupling of proper size, up onto the handle of the tongs. Allow the weight of the rods to rest upon the tongs and then throw the hoist out of gear and by use of the small rope, which is fastened into the eye of the grab hook, pull the hook down again.



Brown's Adjustable Pipe Tongs.

In placing the tongs on the rods, the rods should first be elevated to such a point that the coupling stands about two feet above the top of the ground, or, if drive pipe is used in the hole, about 2 feet above the top of the drive pipe.

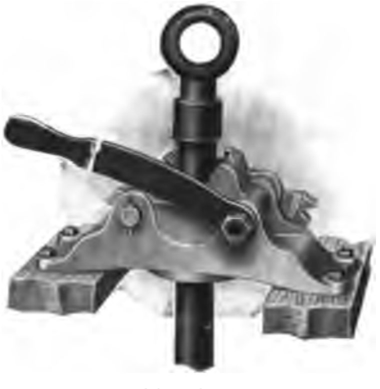


Holding Tongs.

Besides the Brown's tongs referred to above, there are also other appliances used for the same purpose. Thus we have the regular holding tongs which operate practically in the same manner as the Brown's tongs, also the more elaborate rod jack.

The rod jack is very handy in its operation, but inasmuch as an efficient jack is a pretty high priced tool, it is not very generally used.

The manner of operating the rod jack will be readily understood from the cut.



Drill Rod Jack.

As stated above, the rods should be pulled two or more lengths at a time and also, the same joints should be unscrewed each time the rods are hoisted. To enable you to unscrew the same joints each time it is necessary that you keep track of the number of rods in the hole. Thus, if you have twelve rods in the hole and you are pulling two rods at a time, it will require the pulling of six sections of rods, each section made up of two lengths. On the other hand if there are thirteen rods, or in fact any odd number of rods, the first section to be pulled will consist of but one rod and then all the rest of the sections will be made up of two rods.

There is however, one exception to the foregoing advice and that is when valves are used in the rod line. Under such circumstances the different sections to be pulled should be so arranged that the joints containing the valves are not disturbed.

In hoisting sections made up of two rods, the first rod is hoisted until the joint in the lower end comes about 2 feet above the top of the ground, and then the tongs are fastened onto the rods and the grab hook pulled back as already explained.

Next the grab hook is slipped under the lower coupling and the rods hoisted until the lower coupling on the second rod comes above the ground, when the tongs are again fastened onto the rods and grab hook again pulled down.

The rods are now unscrewed at the second joint, and the section made up of the two rods is allowed to stand in the rod ring of the derrick.

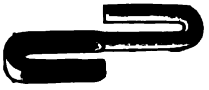
When hoisting the rods care must be taken to guide the top of the rods up through the rod ring, also to prevent the top of the rods from striking the top of the derrick as a kinked rod is liable to result.

To prevent the bottom of the rods from becoming dirty, they should be set on a plank, the plank being so placed that the rods lean a little towards the machine. The cut on the following page shows the manner in which the rods are handled.

As the rods, when pulled, will be full of water and sludge and as this sludge if allowed to run out onto the ground, will make things very disagreeable around the hole it is best to provide a discharge trough as a run-off, or else allow the sludge from the rods to discharge into a bucket. Especially should you make an effort to keep things clean around the hole if you are drilling near a dwelling, as a driller who has the reputation of mudding up everything around the place will not be very anxiously sought by particular people.

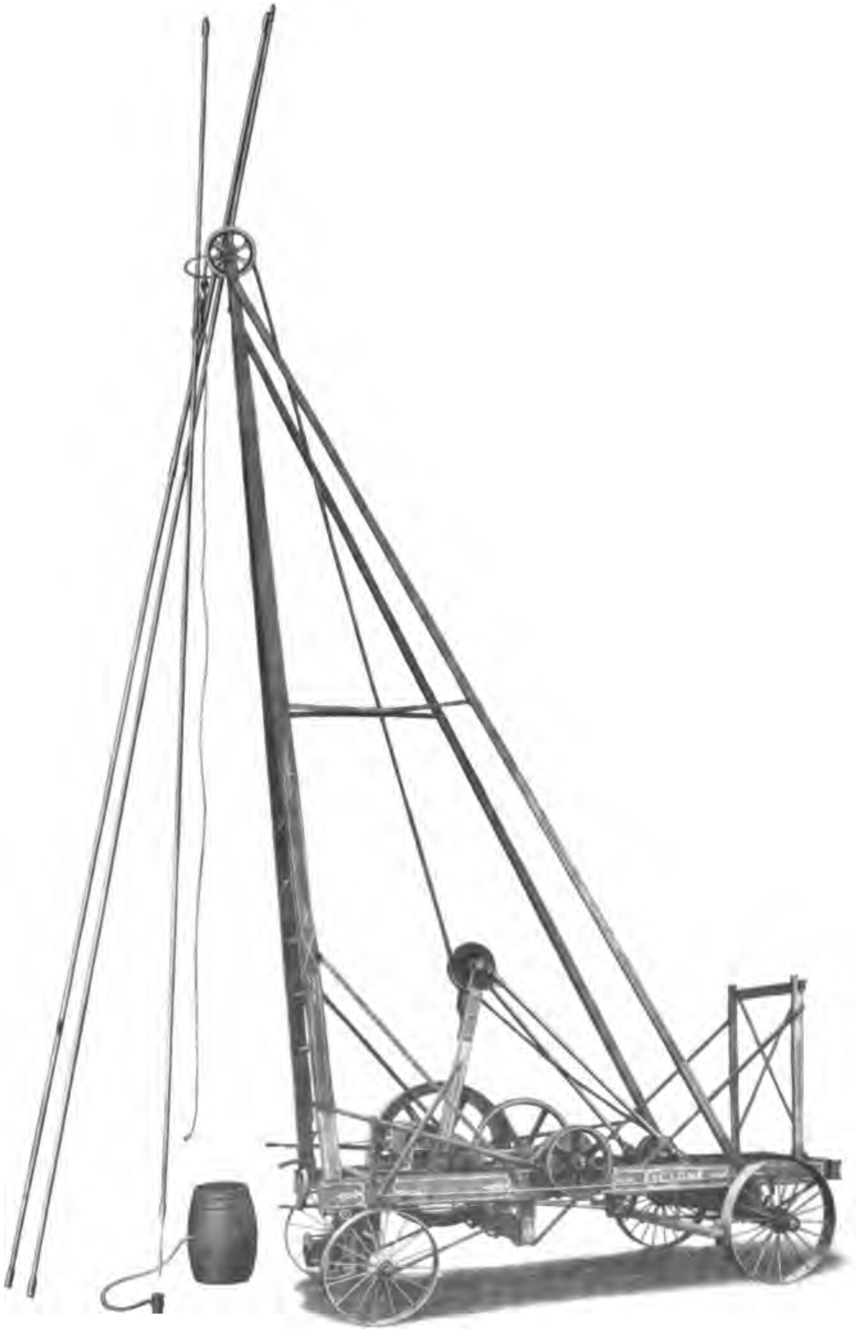
When unscrewing the bit care must be taken to prevent the out-rush of the sludge from washing the ball or valve plate into the drill hole. A good plan is to cover up the hole by placing a plank or an inverted bucket over the drive pipe.

The methods used in handling rods with box-and-pin joints are the same as those already described, with the exception that regular tool wrenches are used in "breaking" the joints and a foot wrench, instead of the Brown's tongs, are used for holding the rods. The accompanying cut shows the construction of a foot wrench.



Foot Wrench.

In using the foot wrench, it is placed below the collar on the joint and then the weight of the rods is allowed to rest upon the wrench while the joint is unscrewed.

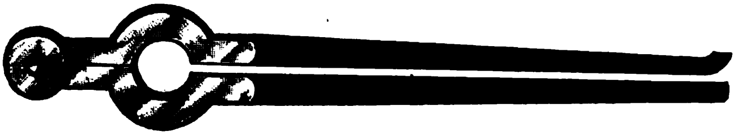


Manner of Standing Drill Rods in the Rod Ring.

## Lowering Drill Rods.

In lowering drill rods into the hole, the operation is practically the reverse of the hoisting operations except where shallow holes are being drilled or where the rods are of such small size that their total weight is not great.

Under either of the two exceptions noted, it is sometimes the custom to use a pair of sliding tongs, as with them a small amount of rods can be more rapidly handled than by using the hoist on the machine.



Sliding Tongs.

In using a pair of sliding tongs, they are clamped around the rod and then the rod allowed to slide through by slightly opening the tongs. The speed with which the rods descend is governed by the pressure on the handle of the tongs.

As already stated under "Hollow Rod Joints," it is necessary to clean off the different joints before screwing them together and thus nothing further along this line will be said at this point.

In screwing up a joint, care must be taken to get the rods fairly well in line when starting the threads so that they will not cross. When two rods are handled at a time, it requires some little knack to balance the rods, but a little experience will soon set you right along this line.

## Drilling Through Clay.

For clay drilling the lower end of the bit should be dressed down thin, and the water channels cut out clean, also the bit should be trimmed up so that there are no square shoulders projecting, as these shoulders will cause the clay to pack on the bit, thus making the tools run "heavy." If a considerable amount of clay drilling is to be handled, it is best to have one or two bits which are used especially for clay work as they can be kept in proper shape to give best results. An ordinary rock bit with the lower end drawn down properly makes a good clay bit, as the thick blade will cause the tools to pump well, while the thin cutting edge will stir up the clay.

In dressing a rock bit for clay drilling, do not bring the edge out to gauge by stoving, as recommended for cable bits on page 76, as this will form shoulders back of the bit corners. The better way is to spread the blade by flattening out the lower end, as this will form a thin edge and will bring the bit out to proper gauge without forming heavy shoulders back of the corners.

Some drillers use a thin, flat bit for clay drilling and while this type of bit is all right for mixing the clay, it does not show the same pumping efficiency as the thick bit with a thin cutting edge.

The most important point to watch in clay drilling, outside of getting a properly constructed bit, is to see that the tools are not allowed to feed downward faster than the clay will mix, and pump. Time cannot be made by crowding a clay hole as the clay must have time to mix with the water before the rods will handle it. As different clays mix differently, it is impossible to give any fixed rule in regard to how fast to feed the tools downward.

A good general rule to follow, however, is to allow the tools to feed as fast as they will without causing them to run "heavy." This can be told by the feel of the rods, also by the condition of the sludge. If the tools do not drop quick and free, or if they seem to "hang" when starting on the up stroke, it is a pretty sure indication that the hole is being "crowded." Under such conditions it is best to elevate the rods a few inches and then come down slowly again in order to give the sludge a chance to thin up. In all clay drilling, the hole should be kept as full of water as possible as the larger the amount of water, the more readily will the clay mix and also the better will the tools pump.

Owing to the fact that clay makes a very thick sludge, it is usually necessary to replace the water in the sludge barrel quite often. However, this depends quite a little upon the character of the clay and thus no fixed rule can be given. In sandy clays it is usually possible to run for a half day or more on one barrel of water, while in some kinds of "greasy" clays, the water must be changed every hour or two.

Where bands of clay alternate with bands of sand or gravel, it is generally best to run the sludge as thick as possible, as a thick sludge will pick up the sand as soon as it is stirred up and will also assist in packing the walls so they will stand without caving. Another advantage of the thick sludge is that it will plaster up the openings in the gravel and thus prevent the water in the hole from being drained off.

What has been said above refers to dry sands and gravels or to any sands and gravels which are not to be used for water and which will be cased off. If you are drilling in a region where each sand and gravel stratum must be tested, then it is best to keep the sludge rather thin so that there will be no danger of plugging the stream with sludge.

In certain "greasy" clays it is almost impossible to make the clay mix, and under such conditions, time can be made by putting two or three, or sometimes even more, buckets full of sharp sand in the sludge barrel. The sand will "cut" the clay, thus causing it to mix.

Sometimes it will be found to be an advantage to use more than one valve in the rod line. Generally one additional valve placed at the top of the first rod above the bit will be sufficient. However, if the sludge is extremely heavy it may be necessary to use more valves, but if so, they should not be placed closer together than every two rods.

The advantage of additional valves in heavy clay drilling is that in case the sludge becomes so thick that the bottom valve is forced from its seat, the valves higher up will still continue pumping and thus give the lower valve a chance to free itself.

As stated under pipe driving, it is often possible to drill to a considerable depth in clay before it is necessary to set any pipe and wherever this is possible, it should be done.

In certain kinds of clay drilling, it is an advantage to use an under-reaming tool in order to enlarge the holes and thus make the pipe drive easier. This will be discussed later under under-reaming tools.

## Drilling Through Sand and Gravel.

In sand and gravel drilling, unless heavy gravels or boulders will be encountered, the cutting edge of the bit should be drawn down thin, as explained under "Drilling Through Clay." The reason for using the thin cutting edge is that it will stir up the sand and gravel more readily. On the other hand, a bit dressed blunt, as in rock drilling, tends to pack the material. However, when the gravel is very coarse, the bit should be dressed rather blunt as it is necessary to break up the larger gravels before they can be gotten rid of. Another reason for dressing the edge rather blunt is that a thin edge will glance off the boulders and thus the tools are liable to be thrown out of line and the hole made crooked.

As a usual thing time can be made by keeping the drive pipe ahead of the hole, or at least by keeping it even with the lower end of the bit.

If the pipe is driven ahead care must be exercised to see that it is not driven onto a boulder, as this is very liable to crimp the end of the pipe or else throw the pipe out of line. You will find these points discussed in the Cable Tool Section, pages 43 to 45 inclusive. To keep the pipe even with the edge of the bit it is necessary to drill and drive at the same time as explained on pages 299 to 301 inclusive.

If it is desired to prospect each gravel stratum for water, it will be necessary to keep the end of the drive pipe open when passing through the gravel and thus it is best not to drive very far ahead at a time. In fact, if the gravel strata are thin it is best not to drive ahead at all, as a stream of water may be shut off without knowing it.

When drilling through quicksand, it is generally necessary to keep the drive pipe a short ways ahead of the hole in order to prevent the sand from rushing into the pipe. The deeper the hole, and thus the higher the pressure behind the sand, the further ahead will it be necessary to keep the pipe. If it is desired to prospect the quicksand for water, the drive pipe should be filled to the top with water before opening up the end of the pipe, as the water will assist in holding back the sand.

When drilling dry gravel, that is, gravel which does not contain any water, the water in the drive pipe can be kept from draining off by using a thick clay sludge in the discharge barrel. This clay sludge can be made either by placing chopped up clay directly into the barrel or else by placing clay in the bottom of the hole and letting the rods mix it. The safer plan is to mix it in the barrel as there is not so much danger of clogging the bit. When bands of clay and dry sand alternate, the clay will keep the sludge thick enough to handle the sand.

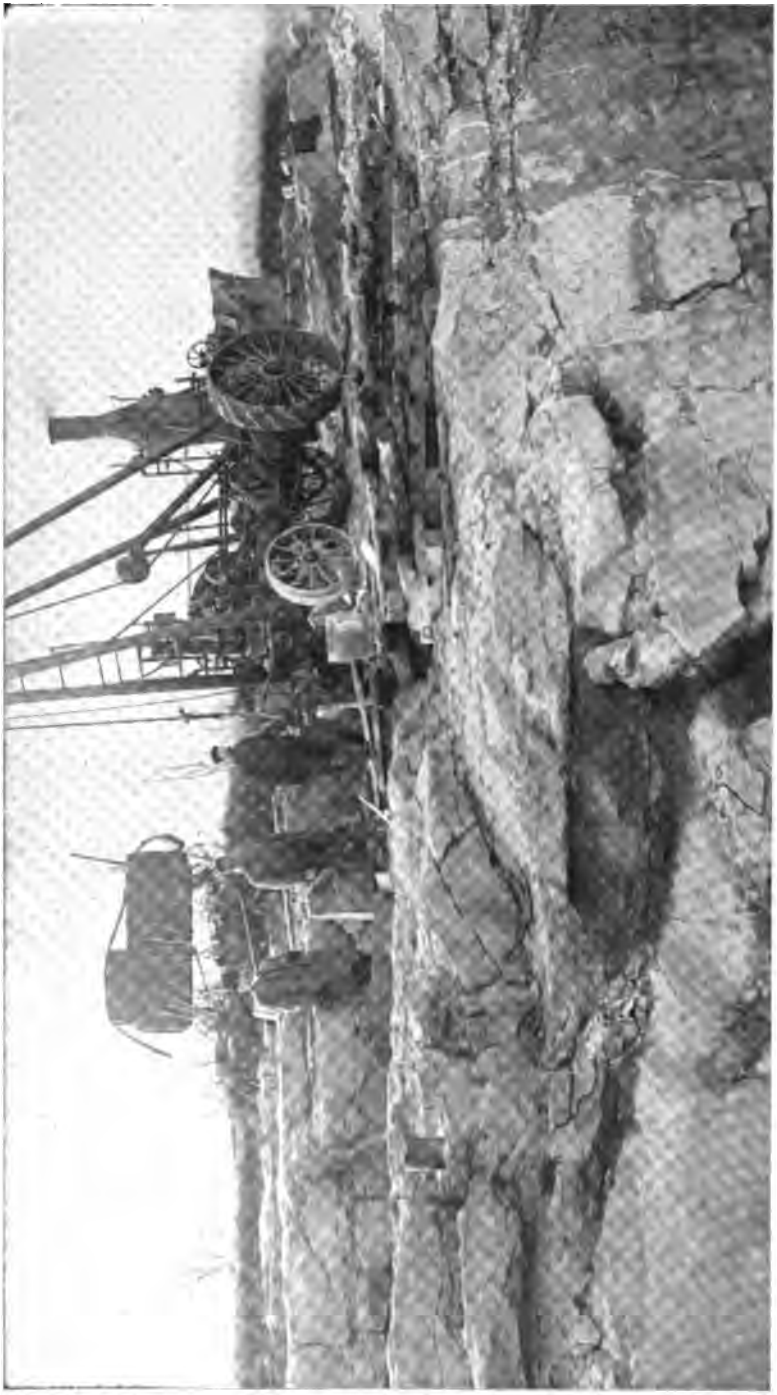
When drilling in water sand, the sludge should not be allowed to get very thick as a thick sludge may plug up the sand enough to prevent the water from coming through freely, and thus give a misleading test.

If it is desired to prospect a stratum of sand or gravel which lies directly below a bed of clay, the drive pipe should be driven down through the clay and the tools should be kept operating at one point long enough to remove all of the heavy sludge. If the water bearing stratum furnishes enough water to feed the rods, the return hose should be removed from the tee on the pipe and the sludge allowed to run out onto the ground. This will soon remove all of the clay from the hole and will clean out the sand or gravel, thus giving it a chance to show its water capacity.

In certain sections of the country there will be found sands which do not pump readily and which cause trouble by plugging the rods. The writer has done quite a little experimenting in sands of this nature and has found the trouble to be due, in the large majority of cases, to one of two causes, first, the sand is clean and free from clay, thus making it impossible to form a sludge thick enough to prevent the sand from settling rapidly and second, the sand is very heavy, making it hard to lift.

The thing to do when either of the above classes of sands is met is to mix clay in the discharge barrel, thus making the sludge thick enough to hold the sand and to prevent it from settling rapidly. In order to prevent the rods from clogging, they should be pumped clean each time it is necessary to stop them. To do this the rods should be elevated a few inches from the bottom of the hole and run for a short time, as this will cause all of the heavy sand and sludge to be discharged from the rods. Thus when adding on change rods, when preparing to pull the rods or when for any other cause it is necessary to stop the tools, they should be elevated a short distance, and pumped until the heavy sand has been gotten rid of. Sometimes it will be found to be an advantage to use more than one valve in the rod line. You will find this point discussed under "Hollow Rod Valves" page 257.

In certain sections of the the country there will be found considerable amounts of cemented gravel or, as it is sometimes called, conglomerate. If



Hollow Rod outfit used for drilling blast holes in Sand Stone quarry.

the cementing material binds the grains into a firm mass, the drilling will be about the same as if extremely hard rock is being penetrated and thus the bit should be dressed for rock work and the tools run the same as for rock drilling. If on the other hand, the grains are not firmly bound, so that they roll out into the hole, then the bit should be dressed with an almost flat edge as the flat edge will crush the pebbles as they fall to the bottom of the hole and will at the same time force itself ahead.

## Drilling Through Bouldry Ground.

For instructions covering this work see pages 45 and 46, as the methods used with cable tools apply to the hollow rod tools, it being taken into consideration however, the difference in operation of the two types of tool equipments and appliances.

For handling bouldry ground, the bit should be dressed the same as for rock drilling unless the boulders are "nested" together for a considerable distance, in which case the bit should be dressed more blunt, something on the order of a reamer.

Care must be exercised in forcing hollow rod tools against boulders as the tool joints are not large and are thus easily sprung out of line. Especially must care be taken with box-and-pin joint tools as driving the bit against a slanting boulder may snap off the pin.

As a rule, time can be made by blasting in bouldry ground and in the large majority of cases the most successful driller, in a bouldry region, will be found to be one that can handle dynamite to the best advantage.

## Drilling Through Rock.

In rock drilling the main points are the dressing of the bit, the adjusting of the stroke and the regulating of the tension of the drill rope.

The dressing of hollow rod bits will be discussed under the next heading and thus will not be gone into further at this point.

In adjusting the stroke no fixed rule can be given inasmuch as conditions vary so greatly. A good general rule to follow, however, is to decrease the length of stroke in proportion to the hardness of the rock and the "meanness" of the drilling. What is here meant by "mean" drilling, is drilling through crushed or shattered rock, crooked holes and the like. As already explained, the stroke should be shortened as the depth increases and thus the factor of depth must also be taken into consideration.

In regulating the tension of the drill rope, the same general rule just given applies. That is, the harder the rock, the stiffer should be the tension, and on the other hand the softer the rock, the more the rope can be let out.

As stated on page 245, a spudder should be so constructed as to be able to run from 40 to 120 strokes per minute, and it is in rock drilling that the high-speed spudder shows to advantage. Thus, when the rock becomes so hard, or the hole so deep that it is not safe to use a heavy blow, the stroke can be shortened up and the tools run at a higher speed, thus maintaining or exceeding the footage made when using the long stroke.

With cable tools, much of the hole made in rock drilling depends upon the crushing effect obtained from the weight of the tools and thus it is necessary to have a long stroke in order to obtain a heavy crushing blow. On the other hand, with hollow rod tools, most of the hole made in rock is due to the chipping action of the cutting edge of the bit and thus the footage made, increases almost in direct ratio to the number of blows delivered.

There is quite a difference of opinion among drillers regarding the length of stroke to use in rock work, some advocating a long stroke, some a medium stroke and some an extremely short stroke. It has been the writer's observation that the short-stroke drillers generally make most hole. It has also been the writer's personal experience that it is better in the large majority of cases to favor the shorter strokes. While in some cases it might be possible to cut a few more feet of hole per unit of time with a longer stroke, still in the long run the short-stroke driller is very apt to show the most feet drilled, due to the fact that he will have less breaks in his rods and less trouble generally, to contend with.

From the above it will be seen that the writer is a short-stroke advocate and while he is willing to admit that many good drill men do not fully agree with him on this proposition, still he would strongly urge every hollow rod beginner to use a short stroke at the start, for even though it might not prove as speedy in your class of rock drilling, still it would be safer. After you have had enough experience to make your judgment good, you can then safely experiment and make changes to suit your conditions.

One of the most troublesome things that a beginner has to contend with in rock drilling is to keep the joints tight. When using rods with coupling joints, the tools should always be turned to the right as this will assist in keeping the joints set up. You will find this point more thoroughly discussed under "Turning the Tools" pages 286 and 287.

When box-and-pin joints come loose in the hole, the trouble is generally due to too much oil or dirt on the joints, or else the joints have not been properly set up. Another cause of loose box-and-pin joints, and one which is hard to detect, is due to a slightly sprung, or bent, pin. When a pin is bent it prevents the shoulders from binding firmly for their full circumference and thus the joint is very liable to "back off" as soon as the tools begin pounding on rock. If the pin is very much sprung the fact can be easily detected as the rods will be thrown out of line very noticeably, but if it is only a slight bend it is very liable to pass unobserved. If you find that a certain joint persists in coming loose in spite of careful cleaning and proper setting up, it will be well to examine it closely to see if the pin is not slightly out of line. A slight "burr" or "bump" on either of the joint shoulders may also cause trouble.

Another cause of box-and-pin joints loosening up, is using too long a stroke. Especially is this so when the rock is very hard. The remedy is obvious—shorten the stroke.

If a driller is paying close attention to business, he will be able to tell the instant a box-and-pin joint comes loose, as a line of rods with all joints set up tight gives forth a clear, clean, metallic sound or as drillers say, the rods "sing." On the other hand, as soon as a joint loosens, the sound becomes "flat."

If you are drilling with coupling-joint tools, a loose joint can be tightened up by letting the rods rest upon the bottom of the hole and twisting them up. With box-and-pin joints however, it is best to bring the loose joint to the surface so that it can be "snapped up" with a set of wrenches, and especially is this so if hard rock is being drilled.

For a description of the drilling characteristics of different classes of rock formations refer to pages 50 to 62 inclusive. While the matter covered by the above pages has to do particularly with cable tool work, still it applies equally well to hollow-rod drilling, it of course being necessary to vary the methods sufficiently to meet the requirements of the hollow-rod system of drilling.

In creviced or shattered rock or in "mean" rock drilling, the rod tools are usually easier to handle than the cable tools. This is due to the fact that the rods furnish a positive connection between the bit and the top of the hole and thus the driller can tell by the feel, exactly what is going on in the bottom of the hole and can so hold the bit that the best results can be obtained.

## Dressing Hollow Rod Bits.

The subject of bit dressing is discussed on pages 63 to 92 inclusive. While these instructions are made up primarily for cable-tool bits, they also apply to hollow rod bits with the exceptions explained below.

The steel used in hollow-rod bits is a much better grade than that used in cable bits and thus it should not be heated to as high a temperature either for dressing or for tempering. A low carbon steel proves very satisfactory for cable bits, its advantage being that it can be heated to a comparatively high temperature, thus making it easy to dress. This point is discussed on page 74. As hollow rod bits are, as a rule much smaller than cable bits, it is possible to use a better grade of steel and still not make them troublesome to dress. Inasmuch as hollow rod bits are usually dressed with comparatively thin cutting edges, it is necessary to use a high carbon steel in order to prevent the edges from breaking down.

As just stated, hollow-rod bits are generally dressed with a thinner cutting edge than that used on cable bits. The following table gives the angles between the bit faces for bits of different sizes when used for drilling in sand and clay, also for drilling in rock.

**Angles Between Bit Faces for Different Sizes of Bits when Used in Different Materials.**

| SIZE OF BIT | 2 | 2½ | 3 | 3½ | 4 |
|---|---|---|---|---|---|
| Angle for Sand and Clay | 30° to 35° | 30° to 35° | 35° to 40° | 35° to 40° | 40° to 45° |
| Angle for Rock | 60 to 70 | 60 to 70 | 70 to 80 | 70 to 80 | 80 to 90 |

The figures given in the above table are not intended as inflexible standards, but simply as guides to indicate what is best for handling general drill work, under the classes of drilling named. Thus, when very hard rock is encountered or when it is necessary to drill through shattered or creviced formation, the edges should be made more blunt. You will find these points more thoroughly discussed on pages 85 and 86.

In heating hollow rod bits for dressing, they sometimes become so hot for their full length that they cannot be handled by hand.

Under such circumstances, a short piece of pipe screwed onto the end, will provide means for handling the bit without trouble.

In tempering a hollow rod bit, do not temper very deep, and never plunge the bit when at a high heat deep down into the water as checks and cracks will result.

## Jetting System.

In the jetting system of drilling the sludge and cuttings are brought to the surface by forcing a stream of water down through the drill rods and allowing it to discharge through holes in the bit. These holes are arranged very similar to the holes in the hydraulic bits already described. In fact, the regular hydraulic bit is often used for jetting work.

The action of the water when forced out through the holes is such that the sludge and cuttings are washed off of the bottom of the drill hole and are then carried upward in the annular space between the outside of the drill rods and the walls of the hole and finally discharged at the top.

In operating the hollow rod outfit by the jetting process, the tools used and the methods employed are largely the same as when the outfits are operated by the hydraulic process and thus the descriptive matter given on pages 243 to 313 inclusive, should be read. Of course that part of the descriptive matter relating to valves and to the self pumping action of the tools does not apply to the present discussion, but these differences will be readily understood by the reader.

The jetting process for certain classes of drill work possesses advantages over the hydraulic system. Thus when large amounts of sand have to be handled, the jetting tools will prove more efficient. Also where large amounts of clay drilling are encountered, the jetting tools are to be preferred. Another advantage of the jetting tools is that with them, holes of comparatively large diameter can be sunk when the conditions are favorable for the use of the hollow rod tools. Thus, through sand and clay, also through soft shales, the jetting tools can be used for drilling holes as large as 12 or 15 inches in diameter. As already stated, this is something which cannot be done when the tools are operated by the hydraulic system owing to the fact that the tools cannot be made to pump when the diameter of the hole greatly exceeds the outside diameter of the drill rods.

## Jetting Pump.

One of the most important items in connection with a jetting outfit is the pump. As the water employed in drilling is used over and over again, it becomes filled with grit and dirt and thus an ordinary piston type of pump would soon be cut out. To avoid this destructive wearing action the pump should be of either the displacement type or the diaphram type. Under ordinary drilling conditions the displacement type is to be preferred, but when extremely gritty water has to be handled, the diaphram pump will give less trouble.

The advantage of the displacement pump over the piston pump is that the plunger does not come in contact with the cylinder walls and thus the wear comes only on the packing. Another advantage is that the packing is all on the outside and is thus readily accessible.

The advantage of the diaphram pump is due to the fact that no moving parts, with the exception of the valves, comes in contact with the water.

The pump used in jetting work whether of the displacement or diaphram type should be so constructed that a steady pressure can be maintained on the rod line and thus the pumps now furnished are usually made up with two or more cylinders. In order to prevent undue strains from being thrown upon the pumping mechanism, the pump should be provided with a safety valve so that in case the rods become choked the pump can free itself. Usually the valve is set to carry a pressure of about 70 to 80 pounds.

As the maximum pressure of the pump will have to be carried by the hose connecting the pump to the water swivel, it is necessary to use a good grade of high pressure hose for this purpose.

## Water Swivel.

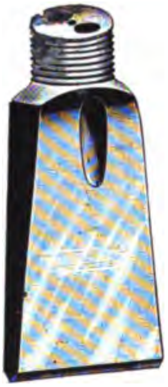
The water swivel used in jetting work is the same as the one illustrated on page 268 with the exception that the discharge stem is made somewhat different.

For hydraulic work the stem is made perfectly smooth at both ends, but for jetting work, owing to the heavy pressure thrown upon the stem by the pump, it is necessary to provide the end of the discharge stem which goes down into the packing box with a heavy collar, this collar serving to hold the stem after the packing is inserted and the packing nut screwed down.

With the exception noted above, the jetting swivel is the same as the hydraulic and thus the descriptive matter given on pages 268 to 272 inclusive, applies.

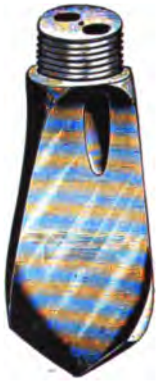
## Drill Bits.

For drilling through unconsolidated deposits such as sand, gravel, clay, etc., the blade of the drill bit used in jetting work is made much thinner and somewhat shorter than the bits used for the same purpose in hydraulic work. By making the blade in this manner it gives the water which is forced down through the rods, a better chance to pick up the sludge, also makes it possible to keep the sludge from accumulating on the blade.

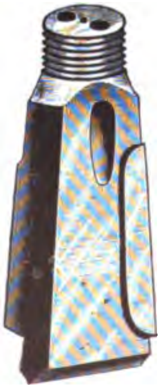

Thin Blade Bit.

To further increase the effectiveness of the water, the side holes are so drilled that the water is discharged down along both sides of the bit blade, thus not only causing the blade to be swept clean, but also directing the water to the point where it will lift the sludge and cuttings in the most efficient manner. The accompanying cut shows the construction of a jetting bit designed for drilling unconsolidated deposits.

For rock work, the bits are made with a much thicker blade, something on the order of the rock bit used in hydraulic work with the exception that the bits are made shorter.


Rotary Bit.

The cut given herewith shows one type of jetting rock bit.


Rock Bit.

When drilling through quick sand, or other fine sand deposits, hole can sometimes be more rapidly made by revolving the bit instead of churning it up and down. For handling such work, a bit shaped like the one shown herewith is used.

Besides the bits illustrated, there are also other shapes and kinds among them being the fish-tail bit, which is used the same as the revolving bit just shown, also the paddy drills which are furnished with two winged blades so constructed and arranged that they will drill a hole somewhat larger than the drive pipe and thus answer the purpose of an enlarging bit.

The paddy drill is used mostly in clay drilling when pipe driving is difficult, but it has been the writer's experience and observation that the paddy drill will not prove effective unless the conditions are exactly suited to its operation.

## Starting a Hole with Jetting Tools.

The methods of starting a hole with jetting tools are the same as those described on pages 282 and 286 inclusive, with the exception that such changes are made as are required for forcing the water down through the rods. Thus the valves are omitted from the rod line and instead of using a blank valve on top of the bit when punching the hole down the first few feet, the water is often turned on from the start.

Regarding drilling the first few feet, however, the method will vary somewhat with conditions. Thus it will sometimes be found more convenient to punch down a few feet before using the water and under such circumstances the blank valve should be used.

In order to take care of the water and sludge which come from the hole, a settling pool should be made by digging a hole in the ground close to the hole being drilled, and then connecting the drill hole to the pool with a shallow ditch. The water and sludge will flow into the pool thus giving the heavier cuttings a chance to settle. Some drillers dig two settling pools close to each other and then connect them together by means of a shallow ditch. When the two pools are used, the sludge and water discharge from the hole into the first pool, which is called the settling pool, and the suction hose from the pump is placed in the second pool, which is called the suction pool. By using the two-hole arrangement, it is possible to get much cleaner water for the pump.

When drilling around dwellings or in a locality where the digging of settling pools would prove an annoyance, the same results can be obtained by driving a piece of casing of proper diameter, solidly into the ground, so driving the casing that it will extend two or three feet above the surface. By placing a tee on top of the casing and providing it with a discharge spout, the water and cuttings can be made to discharge into barrels or tanks which will serve as settling and suction pools.

The method just described is for use when the hole is being started and before any of the regular drive pipe is driven, as after the drive pipe has been started into the ground it can, by placing a tee at the upper end, be made to serve the same purpose as the casing.

The instructions already given under hydraulic work covering pipe driving, drilling and driving, turning the tools, the use of a drilling weight, the use of change rods, hoisting and lowering the rods, cutting threads, making joints, etc., applies to jetting tools as well as to hydraulic tools, it only being necessaay to make such minor changes as are required on account of the different method employed in handling the sludge and water.

## Drilling Through Unconsolidated Deposits.

Under unconsolidated deposits will be included such materials as clay, gravel, alluvium, till and all other materials which are too soft to stand without the use of drive pipe.

When drilling clays, a thin, short bit is necessary. By keeping the bit thin it makes it clean more easily and by having it short, it brings the discharge holes down close to the bottom of the hole, thus giving the water a chance to do its most effective work. The bit shown on page 315 is a good bit for clay drilling.

Another point to watch in clay drilling is to hold a stiff tension in the drill rope, thus preventing the bit from crowding ahead and "mudding up." Clay containing considerable sand will cut and mix very rapidly but "greasy" clays have to be handled more carefully.

When drilling in sands, a short, thin bit is most effective and a heavy water pressure will usually bring the best results. If the sands are heavy and hard to lift, it is well to mix some clay in the suction pool, as the clay will thicken the water and hold the sand in suspension.. When drilling quick sand or any fine sand which has a tendency to rush up into the pipe, it is a good plan to place a valve just above the bit. A valve for this purpose is made to work just the reverse of the hydraulic valve, that is, it will allow the water to be forced down through the rods, but will seat itself when an upward pressure is brought to bear, and thus will prevent the sand from being forced up into the rods, when the pump pressure is removed.

In certain sections of the country large amounts of quick sand have to be penetrated, and it is often necessary to use two water swivels and two discharge hose in order to bring down to the minimum the time required to change drill rods so as to prevent the sand from covering up the tools. When two swivels are used, one is screwed onto the next rod to be used and then when the change is to be made, all that is necessary is to unscrew the swivel from the tools, screw on the new rod with its swivel already attached and proceed with the work.

To expedite matters, the discharge end of the force pump is usually provided with two connections so that both discharge hose can be kept connected. By placing a valve on each outlet, it is possible to run the water through either of the swivels as desired.

As stated under drill bits, time can sometimes be made by revolving the rods instead of reciprocating them. When such is the case, the tension on the drill rope is so adjusted that the bit just rests on the bottom and then as the rods are turned and the sand worked up, the tools are allowed to descend. For work such as described, the fish-tail bit or a bit constructed as shown on page 215 proves most effective.

For drilling through sand containing boulders or for drilling through heavy gravel, a thick bit will prove more effective than a thin one. This is due to the fact that the large gravels will have to be crushed before being washed up. Another disadvantage of the thin bit for such work is that it will glance off of the large stones, thus being liable to make the hole go crooked. For heavy gravel drilling or for boulder work, a regular rock bit with a rather sharp cutting edge will prove most satisfactory.

For drilling through alluvium, till and other forms of unconsolidated deposits, the methods to use are the same as those already outlined or some form or combination of the methods outlined, inasmuch as alluvium, till and other unconsolidated deposits are mixtures of sand, gravel, clay, boulders, etc.

When drilling for water lying above bed rock, care must be exercised to avoid shutting off and passing desirable water strata. Inasmuch as the water which is forced down the drill rods may contain a large amount of sediment, and inasmuch as this sediment will be forced into all of the openings, it is a very easy matter to choke up a water bearing stuatum and thus pass through it without being aware of its existence. Especially is this so if the sand or gravel bearing the water lies immediately below a thick bed of clay as under such circumstances the water being forced down the rods will be full of clay and thus in the very best possible condition for sealing cracks, and porous formations. In fact, this principle is often employed in sealing dry sands and gravels to prevent the loss of the drilling water.

To test a gravel stratum to see whether or not it is water bearing, the hole should be flushed out with clean water, thus washing the "filler" out of the pores and giving the stream a chance to produce. After thoroughly flushing the hole, the water level will, if the stream is a water producer, sink to the pressure point of the water in the gravel. If the gravel is dry, that is, if there is no water in it, the hole should drain itself. In case it is found that water exists, its quantity can be obtained by placing a pump in the well or by running a bailer.

Another method of cleaning a gravel stratum is by placing a valve on top of the bit and then working the tools by the hydraulic method. By operating the tools in this manner you are not only able to clean out the pores in the gravel, but you are also able to get some idea of the amount of water the stratum will furnish by noting the amount discharged by the rods.

## Drilling Through Rock.

Handling rock work with jetting tools is practically the same as handling it with hydraulic tools and thus the instructions given on pages 310 to 313 inclusive, apply, with the exception that the necessary changes for forcing the water down the drill rods must be made.

One of the main points to watch in rock drilling with the jetting tools is to prevent the sealing of the pore spaces in the rock with the mud and sludge carried by the drill water. This danger is not so great in limestone where the water occurs in fairly well defined channels, but in sand rock and rock of similar nature, it is a very easy matter to seal the pores and thus pass by a good water supply. To avoid this mistake, the water used in rock drilling should be as clean as possible, and a careful watch should be kept to detect the presence of pore spaces or openings in the rock. An experienced drill man can nearly always tell the instant a stream is struck by noting the action of the water in the hole. It is a well known fact that an underground stream can be made to absorb an amount of clean water equal to the amount which it will produce, and thus as soon as the stream is struck it will tend to absorb some of the drill water. However, as the drill water will carry considerable sludge and cuttings, it is very liable to clog up the pore spaces and thus, unless careful watch is kept, the stream may be plugged and passed without the driller being aware of its existence.

In certain sections of the country where flowing water is struck, this sealing action of the drill water is taken advantage of to enable the water producing stratum to be drilled into for a considerable distance. Thus in the artesian belt extending throughout certain portions of the states of North Dakota, South Dakota and Montana, the water is encountered in a heavy sandstone member lying below a thick bed of impervious shale. As the sandstone stratum is saturated with water, and as the amount of water which the holes will produce depends largely upon the amount of wall surface of the producing stratum exposed, the drillers aim to drill into the sandstone for a distance of 50 to 100 feet or more. Inasmuch as the water in the section referred to flows at the surface with great pressure, it is necessary to hold it in check when it is desired to drill for a considerable distance into the producing rock and thus the drillers allow the drill water to become quite thick just before sand rock is struck. By adopting this method they completely seal the pores in the rock and are thus able to drill into the rock the required distance.

After having penetrated the rock to the proper point, the hole is flushed out with clean water which removes the sludge from the pores and allows the wells to flow.

As a rule rock drilling will require the circulating of less drill water than when unconsolidated deposits are being penetrated, but this depends upon local conditions and thus no fixed rule can be given.

## Fishing Tools and Tools for Special Conditions.

The fishing jobs which arise when hollow rod tools are used are, in the large majority of cases, not nearly so serious as those which occur with cable tools, neither are they, as a rule, of the same kind. Nevertheless the cable tool fishing instructions given on pages 121 to 177 inclusive, should be read in order to get a general idea of handling troublesome under-ground propositions.

The most common troubles which occur in hollow rod work are as follows:

Rods come unscrewed.
Bit comes unscrewed.
Valve plate and ball become lost in hole.
Tools become fast in the hole.

Other special conditions met with are practically the same as those encountered in cable drilling and you are therefore referred to pages 175 to 192 inclusive where you will find instructions covering subjects as follows:

Taking kinks and crooks out of pipe.
Recovering pump pipe lost in hole.
Straightening a hole.
Reaming a hole.
Pulling drive pipe.
Re-casing a hole.
Pulling casing.

It will of course be understood that in handling the special conditions, just mentioned, the methods advocated on pages 175 to 192 will have to be varied somewhat to adapt them to the rod tools, but this can be readily figured out by the reader. The writer will, however, later on give a few additional methods for handling some of the special conditions, which methods apply only to the rod tools and are thus not covered in the cable tool section.

## Rods Come Unscrewed.

In fishing for a set of rods lost in a hole, the tool used is ordinarily a taper tap, which is illustrated on page 176, and the method of handling which is described on pages 176 and 177.

In case the top of the rod has been battered, it may be necessary to use a milling tool such as is described on pages 138 and 139. Should the milling tool be used, it is more than likely that the walls of the rod will be made so thin that the taper tap will spread the rod and under such conditions a taper socket, or as it is sometimes called, a bell fishing tool should be used. You will find this point discussed on pages 176 and 177.

When drill rods are lost in a hole which has a diameter considerable larger than the outside diameter of the rods, it will usually prove quite a job to locate the end of the rod with a taper tap and thus a taper socket whose lower end just about fills the hole should be used. If the rods are not fast in the hole a home-made tool constructed something on the order of a horn socket, shown on page 136, can be used.

## Bit Comes Unscrewed.

The recovering of a bit lost in the hole will, as a rule, prove more troublesome than the recovering of lost rods. This is due to the fact that it is not so easy to determine when the bit comes off and thus it is liable to be battered somewhat. Another reason is that the bit is so short that it is liable to be forced over into the side of the hole and thus be in such a position that it is hard to get hold of. If the trouble occurs while drilling in rock, the liability of driving the bit into the wall is not so great, but when the walls of the hole are of soft material it does not take much hammering to force the bit out of vertical.

The fishing tools to use for recovering a bit are the same as those described under "Rods Come Unscrewed" and the manner of operating them is practically the same.

If you find after a trial or two that you cannot get hold of the bit you will probably save time by running an impression block in order to determine the position and condition of the top of the bit.

The manner of making an impression block and the methods of using it are described on pages 133 and 134.

If you find that the bit is lying off to one side it may be possible to straighten it up by some one of the methods described on pages 146 and 147. If the hole is in rock it is very probable that the bit can be straightened up so that it can be caught, but if the hole is in dirt or any other soft formation, the chances are not so good. Should the bit become wedged in a soft formation so that it cannot be gotten hold of, then the quickest method of clearing the hole is to shoot the bit back into the wall as described on pages 172 and 173. Should the bit become lost in a rock hole and the sediment settle solidly around it, it probably will be necessary to run a spud as described on pages 128 and 129.

## Valve Plate and Ball Become Lost In Hole.

If the plate and ball become lost while drilling in dirt, it will not pay to attempt to recover them as they are liable to be embeded in the thick sludge, thus making them difficult to locate. Inasmuch as they are of small value and besides will not prove of any inconvenience in continuing the hole, the cheapest and quickest plan is to go ahead with the work as they will be forced out into the walls and out of the way.

If the hole is in rock and only the plate falls into the hole the quickest method of getting rid of it is to drill it up, as the action of the bit will soon grind it into fragments. If, however, the ball is in the hole, it will pay to spend some time in recovering it, inasmuch as it is almost impossible to break it and get rid of it in this manner.

If you have, or can readily secure, a vacuum sand pump, of proper size, it will be an easy matter to clean the hole, as the suction produced by this type of pump is sufficient to sweep the ball into the pump. The vacuum pump referred to is illustrated on page 17.

If you cannot get hold of a vacuum pump, the ball can be recovered by use of an impression block filled with sticky clay or soap. The block is made the same as described on page 133.

To use the impression block, fasten it on the end of the rods and then lower it into the hole until it rests upon the bottom. The weight of the rods will be sufficient to press the ball firmly into the clay, or soap, where it will remain.

If there is considerable sludge or cuttings on the bottom of the hole, it will be necessary to pump these out in order to bring the ball into a position where it can be reached by the block.

## Tools Become Fast in the Hole.

Broadly speaking, there are two ways in which the tools can become fastened in the hole; first, some hard substance falls into the hole, thus wedging the tools, and second, fine sand and gravel rushes up around the rods, thus binding them firmly in the hole.

There are also instances where the fastening of the tools is due to a combination of the two causes named above, but as these are simply special cases of the two broad classifications named and as the methods to be used in recovering the tools will be one or the other of these given or else a combination of the two, they will not be treated separately.

When the tools become fast by something solid wedging them in the hole, they can sometimes be loosened by twisting the rods. In twisting the rods they should always be twisted to the right so as not to loosen the joints. First try twisting the rods when the drill rope is slack and then try the same when the rope has been drawn up taut.

In putting the tension in the rope, it should be done by hand by use of the worm gear, as you will then know exactly the power applied.

It is sometimes an advantage to let sufficient slack into the rope to allow the spudder to pass lower center and then while holding a twisting strain in the rods start the spudder into motion. The driving of the spudder against the rope will cause a blow to be transmitted to the rods which, for loosening tools, is more effective than a straight pull.

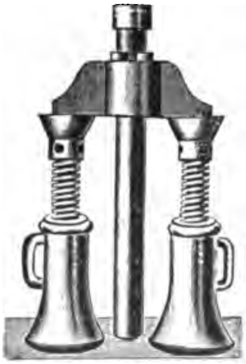
When the fastening of the rods is caused by a small pebble or small piece of rock down along the side, the obstruction can sometimes be crushed by driving upward on the rods with a sledge hammer. To handle this work, the drill rope should first be drawn up good and tight as this will assist the blows and give them greater crushing effect. If you are using a drilling weight or a driving clamp on the rods you can drive up against either of them. If, however, neither clamps nor weight are on the rods, then a pair of tongs or a grab hook can be used. To use either of these latter, they are slipped onto the rod and held against the lower part of one of the couplings and then driven upward. If the rods are fitted with box-and-pin joints, a foot wrench can be used in place of the tongs or grab hook.

If after giving all of the above methods a fair trial, you are still unable to get the tools loose, it will indicate that they are very firmly fastened and the next step will be to arrange for heavy up-driving. For this purpose, the regular hollow-rod pipe-jar device shown on page 185 is used. To arrange this device so that it can be used in connection with the drill rods, it is necessary to secure a piece of pipe of such size that it will fit the pulling plug on the puller which you have and then secure a reducing coupling which will screw onto the rods and also onto the pipe or else into the couplings on the pipe. The length of the piece of pipe should be 3 or 4 feet.

Some drillers carry one of these pieces of pipe and a reducing coupling with them in their regular tool equipment and if you are in a country where caving trouble is experienced, it is a good plan to provide yourself with them at the start, inasmuch as their cost is not great, neither are they bulky to carry about and when they are needed they will more than pay for themselves on the first trouble.

To connect onto the rods, the water-swivel is first unscrewed from the rods, next the reducing coupling is screwed onto the top of the rods and then the short piece of pipe is screwed onto the reducing coupling. After screwing the pipe onto the reducing coupling, the rope hook on the drill rope is passed through the eye of the driver stem and the driver hoisted so that the pulling plug can be screwed into the top of the pipe.

Instructions covering the method of operating the pipe driver when driving up will be found on pages 184 and 185. In driving up on a line of drill rods care must be exercised to prevent too heavy a blow, as hard driving may result in pulling the rods apart. The aim in using the driver is to so adjust the stroke that the obstacle down along the rods will be crushed or if the obstable is of metal and too hard to crush, then to drive with sufficient power to force the rods past the obstruction or else bring it up with the rods.


Small Ring-and-Wedge Rod Puller.

When the rods are very securely fastened, it will sometimes assist matters to hold a steady upward strain on the rods, while the driver is being operated. This can be done by means of a pry pole as described on page 183, or else by means of jacks and a small ring-and-wedge device as shown in cut.

## Tools Become Fastened by Sand.

When sand rushes up around the tools, it is very liable to make them hard to recover. Especially is this so when the sand is very fine or in the nature of a quick sand, inasmuch as a fine sand, when it settles, packs very firmly.

If a drill man is paying close attention to business there is not much excuse for him allowing the tools to become buried by sand as the action of the tools will at once indicate the danger. Thus as soon as the sand enters the hole the tools will be lifted off of the bottom and the drill rope will become slack.

The first thing to do, and it must be done instantly, is to throw the hoist into gear and elevate the tools. Unless the sand has a strong pressure behind it, it will not be necessary to elevate the tools more than 15 or 20 feet as the sand will choke the hole and thus prevent more from coming in. When drilling in a region where it is known beforehand that troublesome quicksand will be penetrated, it is a good plan to keep the hole full of water as this will counterbalance the pressure behind the sand and tend to prevent it from entering with a rush.

If the tools become fast in spite of all you can do, then a quick effort should be made to recover them, as the longer they remain in the hole the more firmly they will be fastened, due to the fact that the sand packs more firmly the longer it stands. The most effective tool to use is the driving device described on page 324. In using the driver, unless the rods start upward with the first few blows, the slack in the rope should be so adjusted that the driver strikes on both the up and down strokes as the up-and-down driving will tend to stir up the sand, thus giving the rods a chance to move. Unless the sand is very firm, it should not require much driving to start the tools, and after they have once started the slack should be so adjusted that the driver strikes only on the up-stroke.

In case the sand is very firm, or if for any other reason the tools cannot be driven up, then the quickest method for recovering the tools, in the large majority of cases, is to pull the drive pipe.

As the sand will have the tools firmly fastened in the pipe, they will come up with it. After the pipe has been pulled upward 15 or 20 feet you should again attach the driver to the rods and make an attempt to loosen them. If the tools will not come then pull the pipe another 15 or 20 feet and again try to move them. Repeat the above operations until the rods loosen or else all of the pipe is pulled out.

Another method of handling the above work is to unscrew the rods down to the sand and then get rid of the sand by jetting it out of the hole. For operating this method, it is necessary to have a set of rods with left-hand threads. In using the left-hand rods a left-hand taper tap is screwed onto the lower end of the rods and then by seating the taper tap in the top of the rods down in the hole, the different sections can be unscrewed and brought to the surface.

After the rods have been unscrewed down to the sand, the sand is jetted out down along the sides of the next lower rod and then this rod is unscrewed and brought to the surface, this method being followed until all of the rods are loose.

The jetting method is a very satisfactory and rapid method of loosening the rods when conditions are favorable for its use and is to be recommended over all others if the space between the outside of the drill rods and the inside of the hole will admit of the using of a small jetting pipe. However, in small holes where the drill rods take up nearly all of the space, the previous method of pulling the pipe is the most satisfactory, according to the experience of the writer, and while it seems, at first thought, to be a hardship to have to "pull the hole" after having drilled it, still time will usually be made by so doing.

If you should be so unfortunate as to get into a hole where it is absolutely impossible to save all of the drill rods, then the left-hand rods and fishing tap come in handy in recovering as many of the rods as possible.

## Under-Reaming With Hollow Rod Tools.

For enlarging a hole below the end of the drive-pipe so that the pipe can follow down without hard driving, an enlarging bit made up as shown on page 180 is often used. Another type of bit used for this purpose is the paddy drill described on page 316.

When using the enlarging bit, it is necessary to keep the hole about 4 to 5 feet ahead of the pipe in order to give the bit a chance to work. When using the paddy bit it is necessary to keep the hole only 7 or 8 inches ahead of the pipe.

Another method often used by drill men for cutting out under the pipe is to bend the lower end of the bottom drill rod a slight amount. By making a slight bend in the rod it throws the cutting end of the bit outward from the center, thus causing it to revolve in a circle larger than that which would be described by a straight rod. The action obtained by bending the rod is practically the same as that of an enlarging bit.

Enlarging and under-reaming bits, when used with hollow rod tools, find their most extensive use in those regions where large amounts of clay have to be drilled through. By cutting the hole ahead of the pipe somewhat larger than the outside diameter of the couplings on the pipe, it makes the driving much easier. Another condition which can be handled to advantage by an enlarging bit or an under-reaming tool is where hard bands are encountered and have to be driven through.

## Shooting Drive Pipe to Recover It.

In pulling drive pipe it will sometimes be found that it is impossible to start the pipe. Under such circumstances the lower joint of pipe should be shot off and then another attempt made to pull it. If the pipe still refuses to come, then the next joint should be shot off and another attempt made, and so on until the pipe starts. In shooting off a joint of pipe the dynamite should be so placed that the top of the dynamite comes within about 8 inches of the coupling between the first and second joints of pipe. By thus placing the dynamite, the top of the lower section of pipe will be blown loose from the coupling without spreading the piece of pipe above. The amount of dynamite to use depends upon the size of the drive pipe. As a rule, 2-inch pipe can be shot off by using one stick of dynamite, while on larger pipe the amount varies according to the size of pipe to be shot.

If it will be necessary for you to make a well in a hole where you have had to shoot off a piece of pipe, then the pipe should be so shot that it will be spread apart for its full length so that when the new line of pipe is driven it will pass down through the piece which has been shot. In many cases, where it has been necessary to shoot off a piece of pipe, it will pay to start a new hole, but where the hole is of considerable depth and the top part of the hole is through clay or material which will stand without serious caving, time can be made by going back into the same hole.

In shooting a piece of pipe to spread it, the dynamite should be distributed along the full length of the pipe and the firing cap should be placed in the top stick. It is not necessary to completely fill the pipe with the dynamite, simply place a quantity of it every two or three feet. Thus, in shooting a two-inch pipe, a stick should be placed as near the bottom as possible and then a stick every two feet until the dynamite comes within six or eight inches of the top of the joint to be shot. For pipe of larger size it will be necessary to use an amount of explosive in proportion to the diameter of the pipe.

In order to properly space dynamite it can be connected together with pieces of small wire.

## Re-Casing Small Holes.

One of the objections argued against the use of hollow-rod tools and small drilled wells is that the holes are so small at the start that there is no chance for re-casing should it become necessary.

Such an objection is without foundation, as it is possible to re-case as often in the smaller holes as it is in the larger where cable tools are used. When we speak of larger holes we mean holes 5½ to 6 inches in diameter, as holes 5½ to 6 inches in size are the largest generally drilled in ordinary water well work. Thus if the hole is 6 inches at the start, it can be re-cased with 4½-inch pipe and that is the end, as the next size of pipe which can be used is 3 inches and this is too small to drill into with cable tools which are of proper size for drilling 6-inch holes. In fact, a string of cable tools which is of proper size for handling 6-inch work to best advantage is most too large to drill 4½-inch holes.

Now, with hollow-rod tools the hole can be started 3 inches in diameter and then re-cased with 2-inch pipe, and even as a last resort, can be re-cased with one-inch pipe.

By using pipe with flush joint couplings the number of times the hole can be re-cased becomes considerable greater. Thus starting with a 3-inch hole the following lines of pipe can be set:

3 inch pipe will take 2½ inch pipe, flush joint.
2½ inch pipe will take 2 inch pipe, flush joint.
2 inch pipe will take 1½ inch pipe, flush joint.
1½ inch pipe will take 1 inch pipe, flush joint.

The main argument against the flush joint pipe is its comparatively high cost. Another disadvantage is that it will not stand heavy driving. This latter objection, of course, does not have any weight when the pipe is used simply for re-casing.

Many drill men do not re-case a hole for its full depth when the re-casing is done to shut off a caving formation. Instead they simply drop a piece of pipe into the hole and then swage out the top so that it makes a tight fit. This method proves very effective for holding out sand and any other caving formation and if the nature or extent of the "cave" is such that in can be shut out by a 20 feet length of pipe, then it is possible to case off the "cave" without greatly reducing the size of the hole, inasmuch as it will not be necessary to use couplings on the piece of pipe and thus a piece of pipe of the largest possible diameter can be used.

In setting the piece of pipe it is usually dropped in, but it can be lowered by using the rods and the taper tap.

In swaging out the top of the pipe after it has been set, an ordinary rock bit can be used by stoving back the corners and rounding them up somewhat.

If the sand comes into the hole in such large amounts that the piece of pipe will not go to the bottom, then it can be seated by jetting it down. If the pressure of the sand is not great it may be possible to seat the pipe by allowing it to rest on the sand and then drill on the inside of it. By drilling on the inside, the pipe can be made to sink as fast as the sand is cleaned out.

# PART IX.

## Finishing Wells.

To properly finish a well a drill man should have some knowledge of the formations in which water occurs. If a driller confines his operations to one locality he soon learns the conditions he has to meet and thus he is able to handle his work, due to the knowledge gained by experience. On the other hand, a drill man operating in different localities ought to have a pretty good general idea of underground-water geology; at least enough to enable him to roughly classify the formations which he is penetrating and to know what to expect in each formation.

Broadly speaking, underground-water occurs in two classes of formations, namely, unconsolidated and consolidated.

Under the unconsolidated deposits we include clay, sand, gravel, till and alluvium.

Under consolidated deposits we include all classes of rock formations from shale to granite. As many of the rock formations have similar characteristics, as far as water bearing ability is concerned, we will discuss those formations which are typical. Thus it will be found that the water bearing features of any rock formation will be similar to one of the following rock classes: Shale, slate, sandstone, limestone and granite. You will note, by referring back to page 54 that this is the same classification which was given to cover drilling characteristics.

In unconsolidated deposits water occurs in the pores between the particles which makes up the deposits. If the deposit is made up of very finely divided particles closely packed together as in clay, the usefulness of the deposit, as a water bearer, will not be great, for while clay may absorb a large quantity of water yet the pores are so fine that the water will be given up too slowly to be of use.

On the other hand, sand and gravel deposits are made up of particles which have comparatively large spaces between them and thus, if water bearing, will yield water in large amounts. The readiness with which water can be obtained from such deposits depends upon the size of the particles. In coarse gravel the water production will be the maximum, but this production will decrease as the gravel becomes finer until in quicksand the rate of flow becomes very small. The reason for the slow travel of water through quicksand is that the sand grains are so fine that they pack closely together, thus decreasing the pore space. While quicksand itself will readily flow, still this is a different proposition from getting the water out of the sand and it is this latter proposition with which the well driller has to contend.

Sand or gravel which contains considerable clay will also give up water much slower than if it is clean, for the reason that the clay will pack into the pores, thus diminishing the rate at which the water can travel.

In till, which is a mixture of clay, sand, gravel and boulders deposited by glaciers, good wells are sometimes made by stopping in a band of clayey gravel and then pumping the well until the clay has been sufficiently drawn out of the gravel to allow it to produce. At first the amount of water which can be obtained from such a well is small, but it gradually increases with steady pumping.

Alluvium is a name given to those formations composed of sand, gravel, clay, boulders, etc., which have been deposited by streams.

Alluvial deposits are usually encountered in the valleys of present streams or in those regions which at one time were stream swept. As the alluvial material was deposited out of and re-arranged by water in motion, it is to be expected that the heavier, coarser material such as the heavier gravels will be encountered in those locations where the currents were strongest and likewise the finer particles further out. Also the heavier sand and gravel will, as a rule, be found at the lower part of an alluvial deposit inasmuch as the running water flowing over the deposits as they were laid down, would tend to wash out the light material. Thus when drilling for water in stream-deposited material, it will often be necessary to drill down to the lower part of the formation in order to get into gravel which is coarse enough to make a good well.

If the alluvium has been deposited on clay, then the chances are that right above the clay the coarsest gravel will be found ; if deposited on rock, the coarsest gravel will be on top of the rock.

Oftentimes in alluvium a hard streak of gravel, or gravel and clay, called hardpan, is encountered just at the base of the deposit. When located at this point, water will usually be found just above or just below it.

This hardpan is sometimes found further up in an alluvial deposit, but this is rare. In till, it is not unusual to strike several bands of hardpan in drilling a depth of a couple hundred feet.

In rock formations water is derived from pore spaces, channels, joints, faults, bedding planes, cavities, foliation planes and cleavage planes.

The water derived from pores is not appreciable except in sandstones and other rock of a sandy or porous nature.

Shale, as a rule, is a poor water producer, this being due to the compactness of the formation, which eliminates pore space, also to the absence of any openings of sufficient size which would serve to store water.

Some shales of a sandy nature will yield considerable water, but such shales are impure and might be termed a shaley sandstone instead of a sandy shale.

When shales have been hardened and shattered by earth movements they often develop openings which will produce considerable water.

Slate is a comparatively poor water producer. Where wells are made in slate it is rarely that a definite channel or opening is struck, most of the water coming into the wells from seeps along the cleavage planes. Where slates have been subjected to earth movements, openings are often formed and these openings may then produce considerable water.

Sandstones are the greatest water producers. Another thing, water derived from sandstone is usually of a better quality than that derived from any other kind of consolidated deposit. This is due to both the filtering power of the sandstone and to the absence of easily soluable matter in the stone.

Almost all water derived from sandstone comes from pore space, and thus all other things being equal, the more porous the rock, or in other words, the larger the grains, the greater its capacity to yield.

Some sandstone formations have had the pores completely filled with silica and where this has occurred the formation is called quartzite.

Quartzite is an extremely hard formation, and owing to having all its pores filled with mineral matter, is almost non water bearing. However, where a quartzite formation has become cracked and shattered, the openings may afford considerable water.

In limestone, the water occurs along the bedding planes between the layers, in cracks and joints, in faults, in channels and cavities. In fact, in limestone it is not unusual to strike openings of large extent which are completely filled with water.

Owing to the readiness with which water may be able to circulate in limestone, it is necessary to exercise considerable care in making limestone wells. While a well may produce abundantly, nevertheless the source of the water may be such as to furnish impurities. The accompanying cut shows a sink hole draining directly into a limestone channel and illustrates the above point.

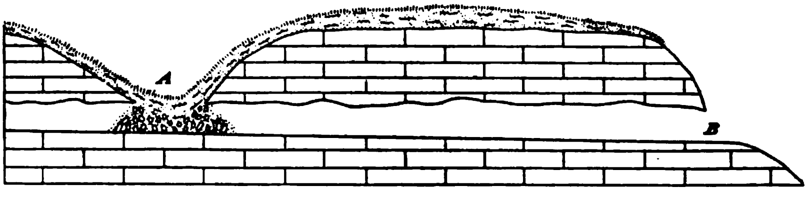


Diagram showing manner in which surface water can drain directly into a limestone channel

In granite the water occurs altogether in joints, and other openings formed when the molten granite cooled or later when the latter was subjected to earth movements. As these openings have but very little filtering effect on the water, it is a good plan to so locate granite wells that they will not be liable to receive impure drainage. The cut shown on the following page gives some idea of the manner in which a granite well cross-cuts various joint planes.

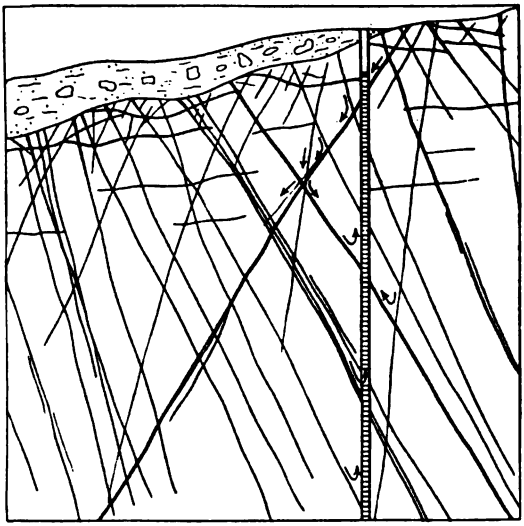


Diagram showing how a well in granite may cut several joint planes.

Summing up the foregoing in regard to rock wells, the following conclusions can be drawn:

Shale, unless sandy, or hard and broken, is not a water producer. It may, however, serve as an important agent in water production by preventing a vein of water from going lower; may also lie above a water bearing formation and thus assist in developing an artesian pressure.

Slate is not a large producer. As the water is derived from seeps in the cleavage planes, the deeper the well, the greater the quantity of water which can be expected, due to the greater number of cleavage planes exposed. In the slate formations which have been shattered or cracked, it is generally possible to get better wells than can be gotten in an unaltered state.

Sandstone is a great water producer. If a sandstone formation lies far enough below the surface to be completely saturated with water and the formation is porous throughout its extent, then the amount of water which a well of given diameter can produce depends upon the depth of the well into the rock.

Limestone, as a rule, is a good producer. Inasmuch as the water occurs in veins, channels, cavities, etc., and is not thoroughly distributed as in sandstone, wells in the same limestone formation, even when within a few feet of each other may vary greatly in capacity, also in depth. As a limestone formation is liable to have water bearing openings throughout its extent, it is to be expected that the deeper the well the greater its production, due to the greater number of openings tapped.

Granite cannot be called a heavy water producer. While the percentage of dry wells in granite is not very great, neither is the percentage of heavy producers very great. The granite wells which show the largest capacity are generally those which penetrate a granite formation lying below a thick bed of gravel or till. The reason for this is that the water from the overlying formation will drain down through the joints and cracks and thus keep the supply in the rock constant. The cut on the next page shows a condition which should produce good granite wells.

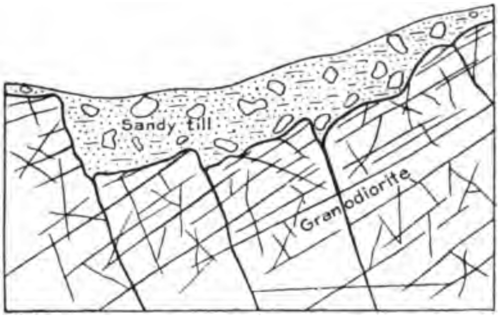


Diagram showing method by which water may enter cracks and joints in granite.

As the water in granite is derived from joints and cracks and as these joints and cracks are, as a rule, most numerous in the upper part of the formation, it is not considered good practice to drill deeper than 300 feet into the granite. Thus, if water is not struck by the time a depth of 300 feet has been reached, it will usually pay to start a new well a few feet from the old one in an effort to strike new joints which are water bearing. The accompanying cut shows how certain wells might miss a water-producing joint while a well a short distance off might be a producer. Thus the wells S, B and D would be dry, while the wells A, C and E would yield water. Another point brought out is that a well such as D might be drilled several hundred feet without striking water, while a well a few feet from D, as E. would strike water at a comparatively shallow depth.

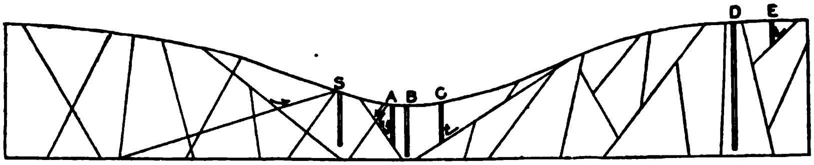


Diagram showing why some granite wells produce and others do not.

The limits of this book will not admit of giving more than the foregoing brief outline of underground-water geology, but as the study of this subject is not only interesting, but also of great value to a drill man, the writer would urge that you study the subject carefully.

Some of the best books written on the subject are published by the United States Geological Survey, the books being classified as Water Supply Papers. Copies of many of the books can be obtained free of charge by addressing, The Director, U. S. Geological Survey, Washington, D. C.

The best method to pursue in getting the books is to first write for the full list published and then send for those books which relate to underground-water conditions.

## Finishing Wells in Sand and Gravel.

The finishing of a well in rock, as a rule, does not involve any extra labor over the drilling of the well. Thus the driving of the pipe to the rock shuts out all loose, ravelly material, and the stream as soon as struck and sufficiently bailed is ready for use.

On the other hand, when wells are made in sand or gravel, it is often necessary to place a screen in the bottom of the well in order to prevent the fine sand from rising in the pipe, a thing which, if it occurs, will result in cutting out the pump leathers and in time is liable to "plug" the well.

When wells are made in coarse sand or gravel, it is not necessary to set a screen, as the particles making up the bed are of sufficient weight to prevent them from lifting. Usually when a well is to be made in such material, the bottom of the drive pipe is drilled full of holes which give the well a better chance to draw. The number of holes drilled depends upon the amount of water to be used, also upon the thickness of the gravel stratum. Thus, if the stratum is only two feet thick, it would be useless to drill the holes for a distance of more than two feet along the length of the pipe. If the stratum is of great thickness, the number of holes can be greatly increased. However, there is not much to be gained by drilling too many holes, as all that is wanted is to get sufficient holes to supply the water as fast as the pipe will handle it. Thus, if the drive pipe is three inches inside diameter and the holes drilled are one-quarter inch, it will require about 1450 holes to equal the capacity of the pipe. If the holes are spaced one-quarter of an inch apart, both around the pipe and along its length, they will take up about 22 inches.

If the gravel contains considerable sand it is best to increase the number of holes, as this will distribute the draft throughout a greater area of the gravel and thus prevent the suction from becoming great enough to move the sand.

Wells are sometimes made in sand and gravel without the use of a screen or without perforating the pipe, simply by packing gravel around the bottom of the pipe. To do this, the pipe is driven down into the sand or gravel to the point where the particles seem to be the coarsest and then the pipe is cleaned out. Next, coarse gravels about the size of hickory nuts are poured into the well, until the bottom of the pipe is filled for a distance of about 2 to 3 inches. Next, lower the drilling tools and by churning them up and down force the gravels out of the pipe. Repeat the above operation three or four times and there will be formed around the end of the pipe a pocket of coarse gravel which will prevent the lighter sand from rising.

Some drillers after forming a pocket, fill up the pipe for a distance of a foot or two with the coarse gravels. This is a pretty good idea if there is a heavy pressure in the sand.

When wells are made in sand which is so light that it will lift or so fine that the rate of travel of the water through it is slow, then the safest plan is to use a screen.

The theory of a screen is the providing of a number of openings which are fine enough to prevent the sand particles from passing and are numerous enough to admit of the required amount of water being drawn through

without causing the rate of travel of the water in the sand to become so great that the sand will pack against the openings. Thus, the size of screen to use depends upon the amount of water to be supplied and the size of the openings depends upon the fineness of the sand.

As an example, suppose that a well three inches in diameter is to yield 15 gallons per minute from a sand of such fineness that the openings in the screen cannot be larger than six one-thousandths of an inch. Suppose further that a screen three feet in length will supply the 15 gallons. Then to get 30 gallons per minute the length of the screen should be at least six feet. If the sand stratum from which the water is to be obtained is only two or three feet thick, thus making it impossible to use a long screen, then it will be necessary to drill a well of larger diameter than otherwise would have to be drilled, if the stratun was of considerable thickness.

While there are many different kinds of screens or strainers on the market, they can be broadly classified under the five following heads:

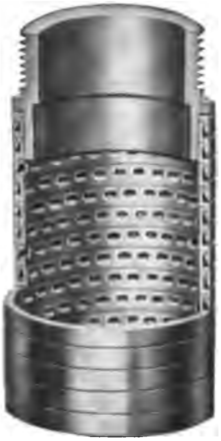
1st. Screens made by covering perforated pipe with either wire gauge, or perforated sheet brass, or both.

2nd. Screens made by perforating pipe and then filling in the perforations with wire gauge.

3rd. Screens made by perforating pipe and then wrapping the pipe with a wedge-shaped brass wire which is so constructed that it forms a thin slot opening on the outside and a larger opening inside.

4th. Screens made of solid brass shells, the openings being made by cutting a series of slots in the shells.

5th. Screens made by winding up a specially constructed hard drawn brass wire which is so shaped that as it is wound it locks together, forming a cylinder having a continuous slotted opening on the outside and perforated openings on the inside.



Johnson Screen.

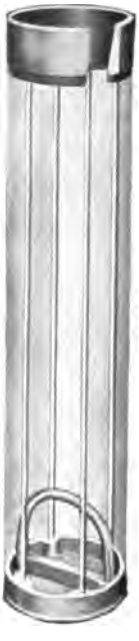
The first two classes are most extensively used as drive points for drive wells. They are also often used in wells where the drive pipe cannot be driven into the gravel stratum and it is necessary to drive a screen point ahead of the pipe.

The third type is largely used in oil-well work in the coastal regions where it is necessary to have a screen of great strength, also one which will not be cut out by sand under high pressure.

The fourth and fifth classes are the ones most extensively used in water well work, where the screens are set by placing them in the bottom of the well and then drawing back the drive pipe.

The large cut on the preceding page shows one of the best type of slotted screens, this being made by A. D. Cook of Lawrenceburg, Indiana. You will note that the slots are finest on the outside and taper larger on the inside. By cutting the slots in this manner, the screen has a chance to clean itself and will thus prevent the packing of fine sand in the slots.

The next cut shows the construction of a built-up screen of the fifth class. This type is known as the Johnson strainer and is made by E. E. Johnson, St. Paul, Minnesota. In order to strengthen this screen so that it will stand up to hard pulling, the sizes from three inches up are furnished with tension rods, as shown herewith.



Tension Rods used in Johnson Screen.

The slots in both the Cook and Johnson screens are listed according to their sizes in thousandths of an inch. The diagram on on the following page shows slots ranging from six-thousandths to sixty-thousandths of an inch.

To set a screen, the drive pipe is first driven into the gravel stratum to the point where it is desired to have the bottom of the screen rest.

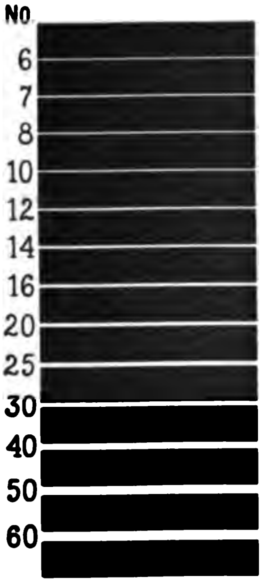
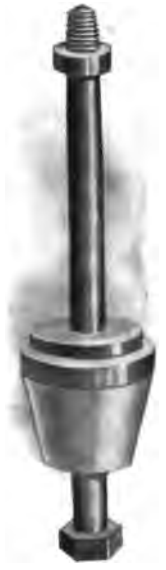


Diagram of Slot Dimensions.

That is, if the water is to be obtained between the depths of 180 and 182 feet, then the drive pipe is to be driven down to a depth of 182 feet.

The screen is lowered into the well by using one-inch pipe, or if the pump to be put in the well has wooden sucker rods then use the wood rods. The screen is attached to the rods by the use of a strainer hook which hooks under the bail at the bottom of the screen.

After the screen has been seated on the bottom, pull back the pipe for the distance it is desired to uncover the screen. Thus, if a three-foot screen is to be set, the pipe will be pulled back three feet and this will then leave a foot to eighteen inches of screen remain up in the drive pipe.



Swedge Block.

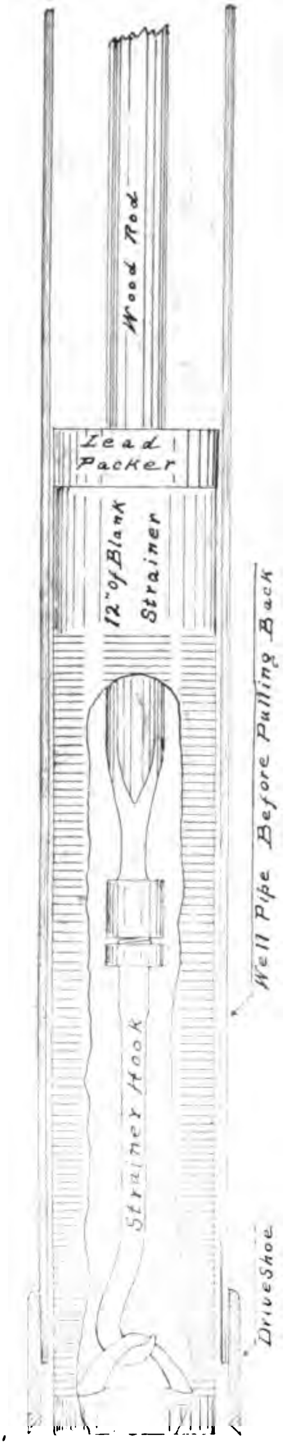
When pulling the pipe, the rods used in lowering the screen should be left in the well so that you can tell whether or not the screen is remaining in position. If the screen starts to rise, it can usually be made to loosen itself from the pipe by driving down lightly in the rods. It may be that the rods will have to be weighted down until after the lower end of the screen has been uncovered for six to eight inches. However, as soon as the screen gets far enough out of the pipe to allow the sand to settle around it no further trouble should be experienced.

Strainer Hook.

After the pipe has been drawn back the proper amount, unhook the strainer hook from the bail and remove the rods.

Next connect the swedge block onto the end of the rods and lower it until it rests on the lead packer which is attached to the top of the strainer. Now, by using a few light blows, expand the lead until it is driven out solidly against the pipe. Do not use heavy blows and do not use many of them—just enough to expand the lead. Remember that the screen may have to be pulled some time.

In swedging do not use a long stroke, as the swedging should be done by driving down on the swedge block and not by hammering the block up and down on the packer. You will note from the cut how a rod passes

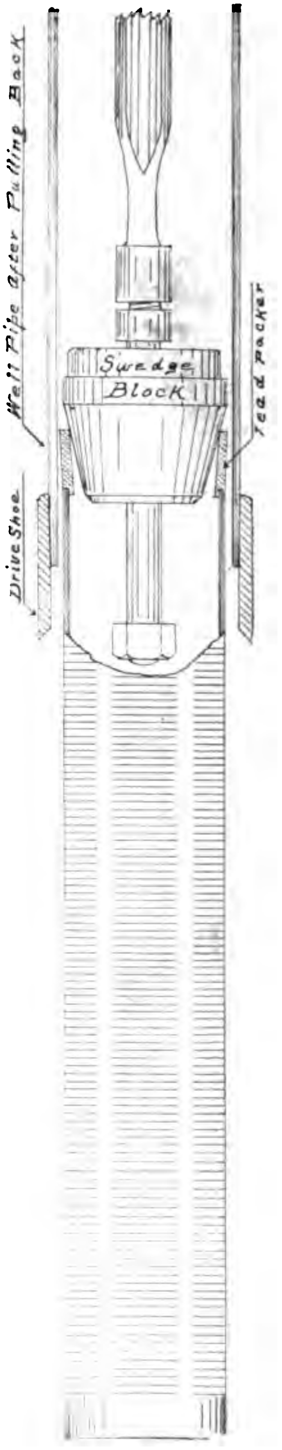


through the block, and in expanding the packer, the stroke should be so adjusted that the rod strikes only on the down stroke.

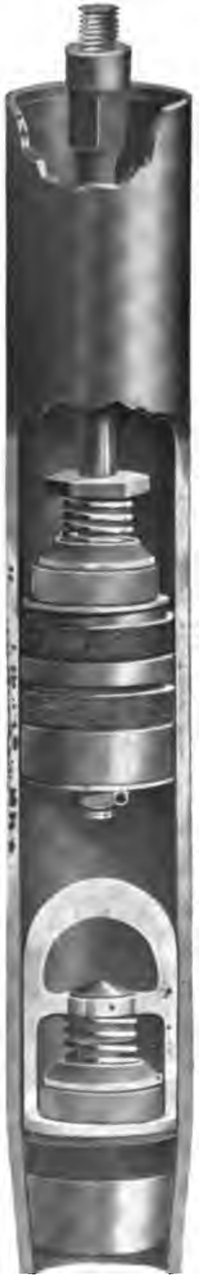
After the lead has been expanded, the swedge block can be loosened by driving up on it with the rods.

The large cut on the left shows the placing of one of the Cook screens on the bottom of the hole, while the cut on the right shows the position of the screen after the pipe has been pulled back, also, the position of the swedge block when the lead packer is being expanded.

In some water bearing sands the stratum is made up of both coarse and fine grains intimately mixed. Where this condition occurs the most satisfactory well can be made by using a screen having rather large openings. The object of this is to provide openings which are large enough to allow the fine sand to pass through and yet small enough to prevent the larger grains from entering the screen. After setting such a screen, the well should be vigorously pumped for several hours as this pumping will remove all of the fine grains and will allow the larger grains to pack around the



screen. After the pumping has removed the fine sand and has packed the coarse grains about the screen, the well will produce the maximum quantity of water without further trouble.



Working Barrel with Check Valve and Plunger in place.

In many small wells which do not use the drive pipe for a cylinder and in many large wells, the working barrel is seated on top of the screen. To do this, a gum packer is pushed down into the tapered opening which has been formed by swedging the lead packer and then the working barrel is driven down into the gum packer. After seating the working barrel, the check valve is lowered until it rests at bottom of the barrel. Next the plunger is lowered into the barrel, the pump rods connected up with the pump standard and the well is ready.

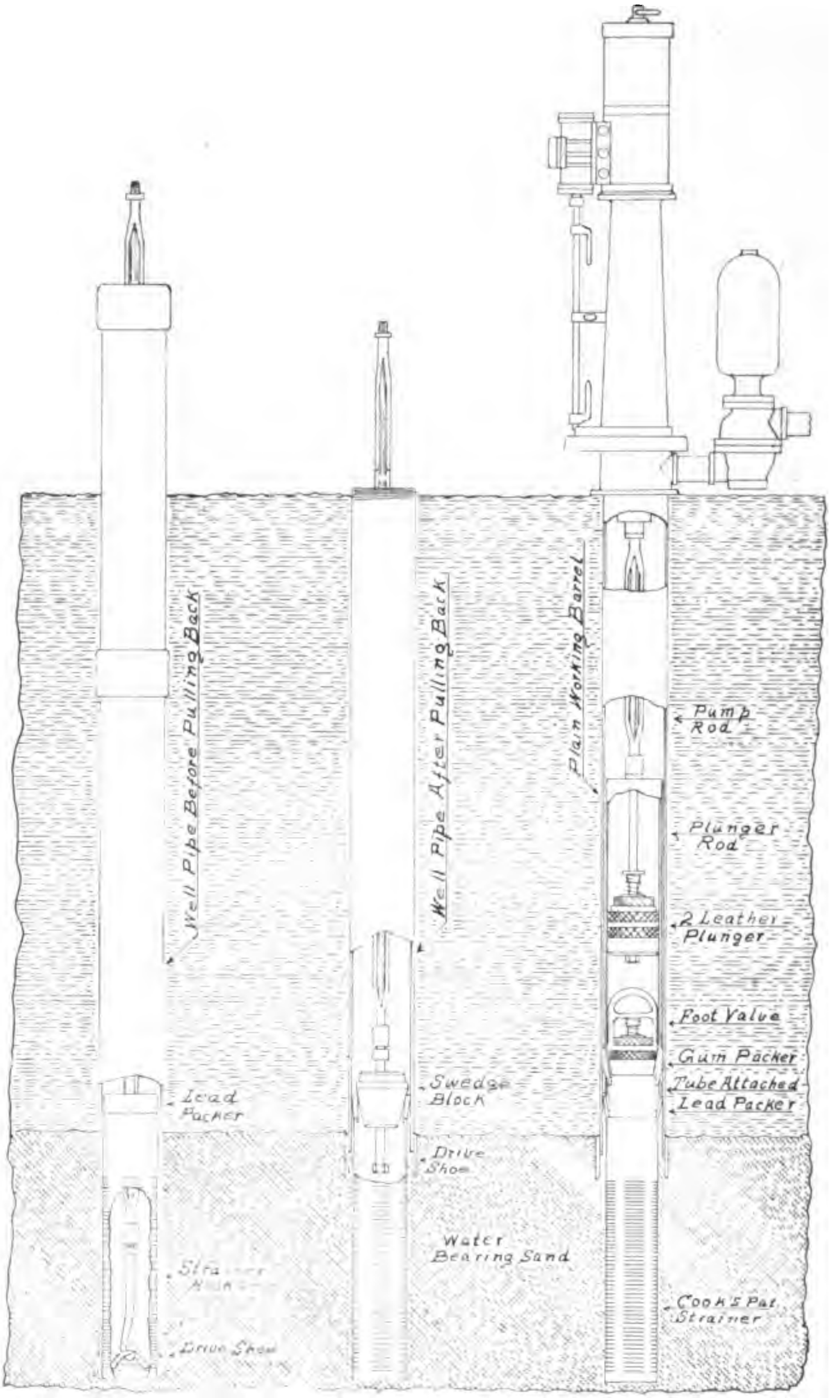
Gum Packer.

In placing the gum packer it is simply dropped into the well. As the bottom of the packer is tapered, it fits the taper of the lead packer. Should the gum packer not seat properly, it can be pushed down by using the rods.

After seating the packer the working barrel is lowered by using a special hook on the end of the rods. To seat the barrel firmly in the packer, drive down on the top of the barrel with the swedge block with large end turned down. You will note from the cut that the bottom of the working barrel is tapered, and the driving will cause this tapered end to be forced into the gum packer where it will be firmly held.

Tapered Check Valve.

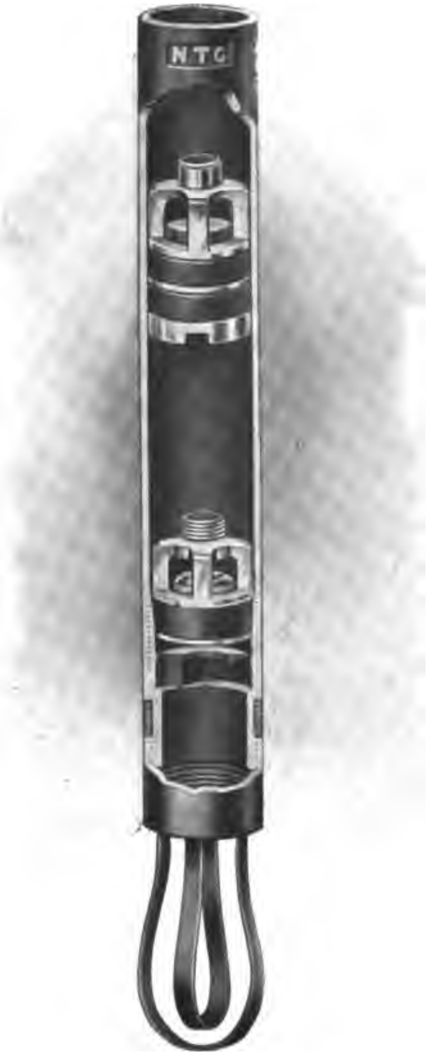
The check valve is next lowered into the working barrel by using the strainer hook. The valve is made tapering to fit the taper in the bottom of the barrel



362 02/05 8
41974

and by allowing the weight of the rods to rest on the valve, it will be forced firmly into the taper.

The large cut shown on opposite page illustrates 3 of the steps in finishing a well, namely: Lowering the screen, swedging the lead packer, and the appearance of the equipment after the working barrel has been set and the pump connected up.

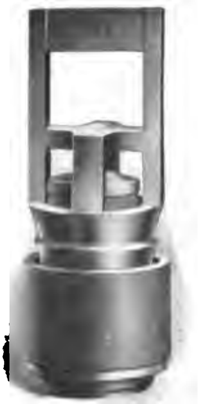


Working Barrel with Spring Dog.

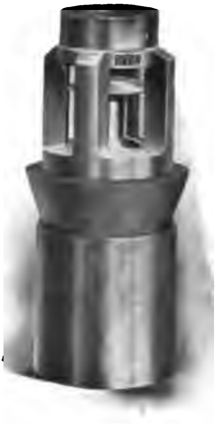
Seating Tool for Spring Dog Cylinder.

Where it is not desired to set the working barrel as low down as the top of the screen, a barrel with a spring dog is used. In this type of barrel, the spring dog on the lower coupling holds firmly to the walls of the inside of the drive pipe and the barrel is locked to the pipe by revolving the barrel which causes the rubber packer just at the top of the spring dog coupling to expand.

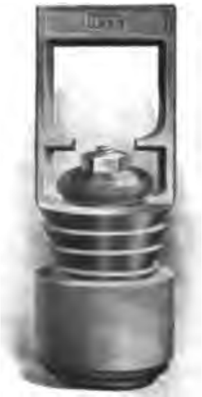
In lowering this type of working barrel into the well and revolving it



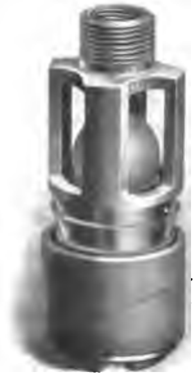
Bale Top Check.



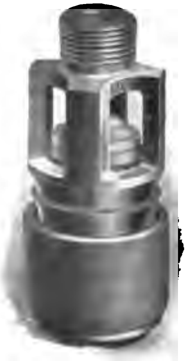
Marcy Check.



Bremer Check.



Ball Check.



Poppet Check.

Spool Check.

Bale Top Ball Check.

Bremer Check with Spring Dog.

Marcy Check with Spring Dog.

to expand the packer, a seating tool connected onto the end of a line of pipe is used. In using the seating tool, it is attached to the working barrel by slipping the head of the tool under the offset ring at the bottom of the barrel.

After the barrel has been locked in the pipe, the check valve is lowered and the plunger inserted as previously described.

The cuts on page 341 show a working barrel and seating tool of the type just described, which are manufactured by the National Tube Company, Pittsburgh, Pa.

The type of check valve to use on different jobs depends somewhat upon local conditions, also upon the notion of the man installing the pump. The check valves illustrated on pages 342 and 343, manufactured by the National Tube Company, cover some of the best known and most universally used types.

In the illustrations you will note that two of the check valves are provided with spring dogs. Valves of this type are used in small wells where no regular working barrel is used and where the plunger works directly against the drive pipe. The spring dog check is also used below certain types of working barrels which are not provided with places to seat a check on the inside.

The most satisfactory installation, unless the well is of very small diameter, say two inches, is to place the check on the inside of the barrel, as this then makes the barrel a complete unit. However, on two-inch wells, the separate check is extensively used as it permits the use of the very largest possible size of check in a pipe of given diameter.

# INDEX

## A

- Air Lift for Pumping........................234
- Alligator Grab............................151-156
  - Home-made...... ........................156
- Auger Stems
  - Size of stem to use...................... 95
  - Table of stem dimensions ........... 96
  - Table of stem lengths........ ........ 96
  - How to connect up in starting hole....................................... 14
  - Drilling large holes with small stems.................................... 98
  - Fishing jobs caused by stems breaking.................................153
  - Size of stem to use on fishing job..131
- Austrian Under Reamer....................181

## B

- Bailers
  - How made ............. ...................107
  - How to handle...........................108
  - Proper size to use.......................109
  - Table of bailer dimensions...........111
  - Table of bailer lengths...............112
  - How to fasten sand line onto...... 16
  - Pumping a bailer........................ 57
  - Kinds of valves used......... .....16-108
  - Re-setting valves......... ........ 108
  - Vacuum bailers and sand pumps.. 17
  - Special types...............................109
  - Fishing for lost bailer .................170
  - Drilling up a bailer lost in hole...171
- Bailer Grab.................... ........ .........170
- Bits for Cable Tools
  - Difference between spudding and rock bits................. ..............101
  - How to connect up in starting hole.......................................... 14
  - Dimensions figured in making a bit.. .............................. ......102
  - Table of bit dimensions...... ........103
  - Why a thin bit makes unsatistory rock bit...........................104
  - Troubles encountered in using small bit in large hole.............104
  - Advantages and disadvantages of all-steel bits......................... 105
  - Dressing bits...... ........ .............. 63
  - Fishing for bit lost in hole.........146
  - Fishing jobs caused by bits breaking.................................156
  - Star bit........................................ 61
  - Mother Hubbard bit...................178
- Bits for Hydraulic Tools...................249
  - Bits with flat blades...................250
  - Bits with fluted blades................250
  - Main dimensions of hydraulic bits ......................................250
  - Proper spacing of holes in bits.....252
  - Pumping action of bits......... .....251
  - Table, bit dimensions, coupling joints. ........ ........................254
  - Table, bit dimensions, box and pin joints ...............................254
- Bits for Jetting Tools ................. .....316
- Bit Hook.............................................146
- Boilers, Steam
  - How to put on fittings................ 6
  - How to fill and get up steam....... 17
- Boulders
  - Drilling through with cable tools.. 45
  - Drilling through with rod tools...311
  - Using dynamite to get rid of........ 45
  - Pulling pipe for shooting............186
- Breaking the Hold of Fishing Tools...174
- Bull-dog Casing Spear......................192
- Bumper
  - The use of when jars are locked...157
  - The use of to loosen tools stuck on bottom.............................162
  - The use of to loosen tools stuck in pipe..................................162

## C

- Cables, Used in Drilling
  - Kind used for cable drilling........193
  - Kind used for rod drilling...........193
  - Weight of different sizes.............196
  - Proper sizes to use for cable drilling......... ......... ...............197
  - Proper sizes to use for rod drilling..282
  - Stringing cable on machine ........ 9
  - Fastening cable in patent rope socket.............................. ...... 10
  - Removing cable from rope socket. 11
- Casing, the Kinds Used..................... 35
  - Table of sizes.. .......................... 36
  - Casing a hole...............................187
  - Pulling casing................. ........191
- Casing a Hole.................................187
  - Use of shear poles and blocks......189
  - Use of elevators..........................190
  - Use of casing swivel ..................190
  - Use of casing disc............. ........190
  - Casing small holes ......................327
  - Pulling casing............ ...............191
- Casing Bowls used on Fishing Jobs.....166
- Casing Swivel......... ......... ...............138
- Casing Pole and Rope...................... 41
- Cementing a Hole
  - To make a tight joint between drive pipe and rock....... ......... 48

- To prevent shattered rock from falling into hole........164
- Center Jar Socket........151
- Change Rods........267
- Clay
  - Drilling with Cable Tools........ 43
  - Use of Clay Socket........ 43
  - Drilling with Hydraulic Tools.....306
  - Drilling with Jetting Tools........318
- Clutch, Cyclone Positive Friction...... 20
- Collar Grab Socket........136
- Combination Socket........130
  - Used for catching rope socket......130
  - Used for catching pin........144
- Crevices
  - Drilling through with cable tools. 61
  - Dynamiting a crevice........ 62
  - Sealing with cement........164
  - Sealing with clay, cable tools......191
  - Sealing with clay, rod tools........292
- Cylinders for Pumps........221
- Curbings for Wells........230

## D

- Derrick
  - How to raise........ 7
  - How to lower........ 8
  - Arranging for hydraulic drilling..288
  - Rod ring used for rod drilling.....304
- Discharge Pipe for Pump........219
- Dressing Bits, Cable Tools
  - Value of a well dressed bit........ 63
  - Kind of forge to use........ 64
  - Kind of fuel to use........ 64
  - Types of blowers used........ 64
  - Making a forge in the ground...... 66
  - Appearance of ground forge........ 70
  - Making a box forge........ 67
  - Making a forge fire........ 69
  - Composition of bit steel:........ 68
  - How to heat a bit........ 70
  - Turning a bit in the fire........ 71
  - Results to be expected from dirty fire........ 72
  - Why bits are burned........ 72
  - Appearance of badly burned bit .. 73
  - Shaping a bit........ 75
  - How to strike in dressing a bit.... 76
  - Names of different parts at end of bit........ 75
  - How to handle a bit........ 76
  - Proper angle between faces........ 76
  - Use of anvil block and plank...... 77
  - Why bits check and crack........ 78
  - Proper amount to stove a bit....... 78
  - Trouble caused by hammering steel when unevenly heated...... 78
  - Importance of clean water channels........ 79
  - Troubles caused by too rapid heating........ 81
  - Filling out broken corners........ 82
  - Importance of the bit gauge....... 85
  - Shaping bits for hard rock........ 85
  - Shaping bits for soft rock........ 85
  - Shaping bits for fissured rock...... 86
  - Shaping bits for sand, gravel, clay 86
  - Appearance of correctly and incorrectly dressed bits........ 87
  - Heating for tempering........ 88
  - Kind of cooling tank to use........ 83
  - Amount of water to temper in..... 89
  - Table showing color of steel at different temperatures........ 91
- Dressing Bits, Hollow Rod Tools.......313
- Drive Clamps, Cable Tools........ 27
- Drive Clamps, Rod Tools........ 300
- Drilling Tools for Cable Drilling........ 14
  - How to connect up........ 14
  - How to handle starting hole....... 22
- Drive Down Socket........ 134
- Drive Head........ 31
- Driving Pipe
  - With cable tools........ 26
  - Use of drive clamps........ 27
  - Kinds of pipe used for drive pipe. 31
  - Kinds of joints used on drive pipe 33
  - Use of drive head........ 31
  - Use of drive shoe........ 30
  - Use of coupling in place of drive shoe........ 29
  - Cleaning threads on pipe........ 41
  - Use of casing pole and rope in screwing up joints........ 41
  - Use of pipe clamps........ 42
  - Seating pipe in the rock........ 46
- Driving Pipe
  - With rod tools........293
  - Depth to drill before driving.......293
  - Weight of driver to use........294
  - Lengths of joints to drive........296
  - Drilling and driving at same time.299
- Drive Shoe........ 30
- Dynamite
  - How to use on boulders........ 45
  - Used in straightening a hole....... 62
  - Used in limestone drilling........ 59
  - Pulling pipe for dynamiting........186
  - Arranging wires when pulling pipe........186
  - Used in shooting off pipe........326

## E

- Engines, Steam
  - Putting on fittings........ 4
  - How to start and handle........ 18
- Enlarging a Hole
  - With cable tools........180
  - With rod tools........326
- Elevators........190

## F

- Finishing Wells........329
  - In sand and gravel........333
- Fishing Jobs, Cable Tools
  - General instructions covering......121
  - The most common causes of........122

- Cable parts when tools are not fast....123
- Cable parts when tools are fast....125
- The use of a hook rope knife......125
- The use of a rope chopper..........128
- Spudding around tools to loosen them.....128
- Running a combination socket.....130
- Forcing combination socket over a swelled rope socket..............131
- Setting the slips in a combination socket..............132
- How to make and use an impression block..............133
- Using a drive down socket to reduce the top of rope socket......134
- Slip socket, how used ..............135
- Horn socket, how used..............136
- Long friction socket, how used...136
- Collar grab socket, how used......137
- Reaming the rope out of socket...137
- Twist drill spear, how used.........137
- Milling socket, how used...........138
- Running a spear to loosen tools...140
- Rope pulls out of socket............143
- Joint comes unscrewed..............143
- Screwing joints together in the hole..............144
- Straightening up a bit lost in the hole..............146
- Jars break.....147
- Stem breaks..............153
- Using a rasp to reduce a collar....153
- Reaming the hole above a set of tools..............154
- Square socket, when used.......... 155
- Bit breaks..............156
- Removing a small piece of steel from the bottom of hole..........156
- Something falls in on top of the tools..............157
- Loosening jars with a bumper.....157
- Cutting rope at top of socket.......159
- Tools become fastened below the jars..............161
- Tools become stuck on bottom of hole..............162
- Tools become stuck in the pipe...162
- Gravel runs into hole under drive pipe..............163
- Top of bed rock spalls off............165
- Bailer becomes lost in hole..........170
- Something falls in on top of bailer..............171
- Valve pulls out of bailer.............172
- Breaking the hold of fishing tools.174
- Taking kinks and crooks out of pipe..............175
- Recovering pump pipe lost in hole..............176

Fishing Jobs, Rod Tools..................320
- Rods become unscrewed.............321
- Bit becomes unscrewed..............321
- Valve plate and ball become lost in hole..............322
- Rods become wedged in hole.......323
- Rods become fastened by sand....324

Foot Wrench..............304
Forgie Jack.............. 15
Friction Socket..............136

G

Grab Hook..............302
Granite
- Drilling characteristics.............. 60
- Occurrence of water in..............331

Gravel
- Drilling with cable tools....... ..... 43
- Drilling with hydraulic tools......308
- Drilling with jetting tools..........318
- Cable-tool fishing jobs caused by.163
- Rod-tool fishing jobs caused by...324
- Occurrence of water in....... ......329
- Making wells in..............333
- Making gravel pocket at end of pipe..............334
- Setting screens in..............336

H

Handle, Drill for Rod Tools..............287
Holding Tongs..............303
Hollow Rod Tools
- General description..............243
- Hydraulic system..............248
- Jetting system..............314

Hook, Rope for Rod Tools..............283
Horn Socket..............136
Hydraulic System of Drilling............248
- Size of rope to use..............282
- Type of rope hook to use...........283
- Starting a hole with hydraulic tools..............282
- Starting in dirt...............r.........283
- Starting in sand or gravel...........284
- Starting on rock..............284
- The length of stroke to use.........284
- The speed to run..... ..............285
- Turning the tools............ .........286
- Arranging the outfit for pumping..............287
- Amount of water required to make rods pump..............291
- Driving pipe..............293
- Hoisting drill rods..............301
- Standing rods in the derrick........305
- Lowering rods into the hole........306
- Drilling through clay..............306
- Drilling through sand and gravel.308
- Drilling through bouldry ground.311
- Drilling in rock..............311

I

Impression Block..............133
- Used to get impression of lost tools..............134
- Used to recover small parts........323

## J

- Jars, Drilling
  - Why they are used........51
  - How they are made........98
  - Proper size to use........99
  - How to connect onto tools........50
  - How to use........51
  - Testing to detect breaks........52
  - Value of jars on fishing jobs........123
  - Long-stroke jars........123
  - Fishing jobs caused by broken jars........147
  - Rope knife jars........126
  - Swivel jars........160
- Jar Latch Socket........149
- Jar Tongue Socket........149
- Jetting System of Drilling........314
  - Type of pump to use........315
  - Type of water swivel........315
  - Kinds of bits used........316
  - Starting a hole with jetting tools........317
  - Drilling through sand, gravel and clay........318
  - Drilling through rock........319
- Joints Used on Cable Tools
  - How to take care of........12
  - How joints are made........113
  - Why taper joints are used........113
  - Dimensions figured in making taper joint........114
  - Table of joint dimensions........116
  - Taper joint templates........120
- Joints Used on Hollow Rod Tools........272
  - The coupling joint........273
  - Cutting threads for coupling joint........273
  - Length to cut threads........274
  - Types of couplings used........275
  - Reducer couplings........276
  - Box and pin joints........276
  - How to connect up box and pin joints........278
  - Dimensions of box and pin joints........279

## K

- Kearne's Hole Straightening Bit........178
- Knots and Splices........199

## L

- Limestone
  - Drilling characteristics........58
  - Occurrence of water in........331

## M

- Mack's Hole Straightening Collars........178
- Manila Drilling Cable........193
- McCleary's Enlarging Bit........180
- Milling Socket
  - Used on cable tools........138
  - Used on rod tools........321
- Mother Hubbard Bit
  - Used in granite drilling........61
  - Used in straightening crooked hole........178
- Mouse Trap Bailer........128

## N

- New Era Rope Socket........94

## O

- Oiling Machine........17

## P

- Patent Rope Socket........94
  - Setting rope in........10
  - Removing rope from........11
- Pipe
  - Kinds used in well drilling........31
  - Kinds of couplings and joints used........33
  - Table of dimensions of standard pipe........34
  - Table of dimensions of casing........36
  - Table of dimensions of pipe couplings........38
  - Use of galvanized pipe........39
  - Cleaning pipe threads........41
  - Use of casing pole and rope........41
  - Pulling pipe........181
  - Shooting pipe........326
- Pipe Clamps, How Made and Used........42
- Pipe Jar Device, Cable Tools........185
- Pipe Jar Device, Rod Tools........185
- Pneumatic Displacement Pump........235
- Pry Pole for Pulling Pipe........183
- Pulling Casing........191
- Pulling Pipe........181
  - Pulling with jacks........182
  - Pulling with pry-pole........183
  - Pulling with pipe-jar devices........184
  - Pulling pipe to recover lost tools........162
  - Use of shear poles in pulling pipe........167
- Pumping Equipments
  - General discussion........215
  - Pump standards........216
  - Pump rods........217
  - Table of rod sizes........218
  - Discharge pipe........219
  - Proper size discharge pipe to use........219
  - Table showing weight of water in discharge pipe........220
  - Table showing pressure of water in discharge pipe........220
  - Table showing friction of water in discharge pipe........221
  - Pump cylinders, using independent discharge pipe........222
  - Pump cylinders, using drive pipe for discharge pipe........223
  - Table of cylinder capacities........224
  - Table of plunger loads........225
  - Table showing amount water discharged at each stroke........226

- Proper size of cylinder to use......228
- Suction pipe..............................228
- Installing a pump.......................229
- Well curbing.............. ..............230
- Sub-wells for wind pumps...........232
- Heavy pump installations............233
- Pumping with compressed air......234
- Pneumatic displacement pump....235

## R

- Raising Derrick.................. ............ 7
- Rasp, Used for Reducing Battered Tools............... .....................153
- Reamer for Cable Tools....................178
- Reaming a Hole..............................179
  - Use of an enlarging bit...............180
  - Use of under-reamer...................181
  - Reaming to recover lost tools......154
  - Reaming for setting casing... .....179
- Ring and Wedge Pipe Puller.............183
- Rock Drilling
  - Drilling with cable tools ............ 52
  - Adjusting stroke for rock drilling. 52
  - Amount of water to use.............. 52
  - Thickness of sludge to use.......... 53
  - Learning the feel of the cable......145
  - Drilling in shale......................... 54
  - Drilling in slate.......................... 55
  - Drilling in sandstone................. 56
  - Drilling in limestone.................. 58
  - Drilling in granite ..................... 60
  - Drilling rock with hydraulic tools.311
  - Drilling rock with jetting tools...319
- Rods Used in Hollow Rod Drilling....260
  - Diagram of rod thicknesses.........262
  - Use of X and XX pipe...............263
  - Use of swaged rods. ....... ..........263
  - Length of rod to use................. 266
  - Use of change rods....................267
  - Hoisting rods from hole........ .....301
  - Standing rods in derrick............305
  - Lowering rods into hole..............306
  - Straightening bent rods ..............266
  - Fishing for lost rods...................321
  - Use of left-hand rods................ .325
- Rod Jack for Rod Tools...................303
- Rope, Kinds Used in Well Drilling....193
- Rope Chopper...... . ........ ...............128
- Rope Knife, Hook Type..................125
- Rope Knife Jars....... ............... ......126
- Rope Knife Sinker Rod.......... .........127
- Rope Knife, Horseshoe Type............159
- Rope Knife Swivel Jars....................160
- Rope Sockets
  - Different kinds used.................. 93
  - Setting rope in patent socket...... 10
  - Setting rope in wing socket......... 93
  - Setting rope in New Era socket... 94
  - Setting rope in sub-socket.......... 94
  - Connecting up socket in starting hole.................................... 14
  - Fishing for rope socket with combination socket.......................130
  - Reducing top of swelled socket with drive-down socket. ......... 134
  - Reducing top of swelled socket with milling socket.................138
  - Reaming rope out of socket lost in hole................................ 137
  - Catching socket with twist drill spear..................... ..................137
- Rope Spear............ ......... .............123

## S

- Sand
  - How to drill with cable tools ..... 43
  - How to drill with hydraulic tools.308
  - How to drill with jetting tools....318
  - Occurrence of water in...... ........329
  - Making wells in..........................333
  - Setting screens in......................336
- Sandstone
  - Drilling characteristics............... 56
  - Occurrence of water in .............331
- Screens
  - Types used in well work.............335
  - Setting screens..........................336
- Setting-up Drilling Machine...... ...... 6
- Shale
  - Drilling characteristics............... 54
  - Occurrence of water in...............330
- Shear Poles for Pulling Casing..........167
- Sinker Bar for Cable Tools.............. 95
- Sinker Rod for Rope Knife..............127
- Slate
  - Drilling characteristics............... 54
  - Occurrence of water in..............330
- Sliding Tongs..................................306
- Slip Sockets....................................135
- Spear for Drilling Around Lost Tools.140
- Splicing Manila Rope......................199
- Splicing Wire Rope.........................209
- Spud for Cable Tools.......................129
  - Home-made spud............ .........128
- Spudder, Theory and Action of........ 23
- Square Socket.................................155
- Star Bit Used in Granite Drilling....... 61
- Starting a Hole with Cable Tools...... 22
  - Tools to use and how to connect up................ ............... ...... 14
- Starting a Hole with Hydraulic Tools 282
- Starting a Hole with Jetting Tools....317
- Straightening a Hole...................61-177
- Straightening Drive Pipe..................175
- Sub Socket Rope Sockets ........ ...... 94
- Substitutes Used with Cable Tools.....119
- Sub-Wells for Wind Pumps...............232
- Suction Pipe for Pumps....................228
- Swage for Straightening Pipe... ........175
- Swivel Hook with Pin......................120
- Swivel with Box................ ....... ...120
- Swivel Jars......................................160

## T

- Taper Tap.......................................176
- Temper Screws ...............................241

Thread Chaser for Cleaning Pipe Threads........................................ 41

Turning Tools

- When necessary to turn cable tools........................................ 25
- Turning hollow rod tools ...........286

Twist Drill Spear..............................137

- Catching a rope socket with........138

## U

Under-reaming with Cable Tools.......180

Under-reaming with Rod Tools.........326

Unloading Drilling Machine from Car. 4

## V

Vacuum Sand Pumps........................ 17

Valve Cage Used in Hydraulic Drilling ................. ...........................259

Valves, Check Used in Working Barrels..............................339-342-343

- Seating working-barrel check valves....................................339
- Seating spring-dog check valves..344

Valves Used in Bailers...................... 16

- Fishing for bailer valves.............172

Valves Used in Hydraulic Drilling.....257

- Use of blank valve.......................259
- Fishing for lost valves....... ........322

## W

Walking Beams

- When and why used...................237
- Different types used...................238

Water Swivels

- Main requirements of. ...............268
- Parts composing........................268
- Putting in new ball bearings.......269
- How to pack swivel....................271
- Troubles caused by leaky swivel..271
- Quick repair bail ........................272
- Type used in jetting drilling.......315

Weight, Drilling for Rod Tools.........280

Wing Rope Socket............................ 93

Wire Rope.......................................209

- Drilling with..............................213

Working Barrels........................339-341

Wrenches, Cable Tool ........... ......... 51

Wrenching Bar & Chains................. 15

89088944020

b89088944020a

K.F. WENDT LIBRARY
UW COLLEGE OF ENGR.
215 N. RANDALL AVENUE
MADISON, WI 53706